Subsoil amelioration – four years on

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Key Findings

- The application of high rates of chicken litter or synthetic fertiliser to the surface or subsoil (in 2015) did not increase grain yields in 2018 above the untreated controls.
- At the Hill River sites, the long-term cumulative grain yields over the four years were higher in response to the application of chicken litter or synthetic fertiliser amendments in 2015. This was mostly due to high wheat yields in 2016.
- Across seven trials in the Mid-North and Upper Yorke Peninsula there have been inconsistent yield responses from subsoil amelioration. The impact of season and crop type has also had a large effect on yield response.

Why do the trial?

Subsoil constraints are known to have a large impact on grain yields in the Mid-North of SA. Trials in other regions including south western Vic have reported large yield responses (up to 60% yield increase in 1st year) from treatments of deep ripping and deep placement of high rates (up to 20 t/ha) of chicken litter. The grain yield response is thought to be coming from increasing the plant available water holding capacity of these soils by improving the structure of the subsoil. Although the cost associated with implementing these treatments is high, with these reported yield gains it is possible to pay for the treatments in the first season.

How was it done?

Seven randomised complete block design trials with three replicates of the same eight treatments (Table 1) were established in March 2015. The trials were located in three different geographic areas including two near Clare at Hill River, two at Hart and three at Bute. At each location the trials were located on different soil types which are described below.

Table 1. Treatment list for the 7 subsoil manuring sites established in 2015.

Treatment	Nutrition	Ripping	Placement
1	Nil	No	Nil
2	Nil	Yes	Nil
3	20 t/ha chicken litter	No	Surface
4	20 t/ha chicken litter	Yes	Surface
5	20 t/ha chicken litter	Yes	Subsoil
6	3 t/ha synthetic fertiliser	No	Surface
7	3 t/ha synthetic fertiliser	Yes	Surface
8	3 t/ha synthetic fertiliser	Yes	Subsoil

Plot size	2.5 m x 12.0 m
Seeding date	Hill River: 18th April Hart: 30th May Bute: 2nd May
Main treatments applied in 2015	As per treatment list (Table 1)
2018 crop and annual fertiliser	Hill River: 1.9 kg/ha 45Y91, 100 kg/ha 28:13 kg/ha IBS + 2 t/ha chicken litter and 1 t/ha gypsum pre seeding + 80 kg/ha urea 2nd July + 100 kg/ha Urea 27th July Hart: 70 kg/ha Commander barley, 100 kg/ha DAP + 65 kg/ha Urea 25th July Bute Mid: 90 kg/ha Trojan wheat, 90 kg/ha DAP + 50 kg/ha Urea 19th July Bute SE: 90 kg/ha Trojan wheat, 80 kg/ha DAP Bute NW: 80 kg/ha Mulgara oats, 80 kg/ha DAP

Sites and soil types

Hart East	Calcareous gradational clay loam Subsoil constraint: High pH and moderate to high ESP below 30cm
Hart West	Calcareous loam Subsoil constraint: High pH, Boron and ESP below 30cm
Bute Northwest	Calcareous transitional cracking clay Subsoil constraint: High pH, Boron and ESP below 30cm
Bute Mid	Calcareous loam Subsoil constraint: High pH, Boron and ESP below 60cm
Bute Southeast	Grey cracking clay with high exchangeable sodium at depth Subsoil constraint: High pH, Boron and ESP below 30cm
Hill River East	Black cracking clay
Hill River West	Loam over red clay Subsoil constraint: Moderate ESP below 60cm and moderate Boron below 90cm

The initial treatments (Table 1) were established prior to sowing in 2015. Ripping and subsoil treatments were applied with a purpose built trial machine loaned from Victoria DPI. The machine is capable of ripping to a depth of 600mm and applying large volumes of product to a depth of 400 mm. Chicken litter was sourced from three separate chicken sheds for ease of freight, the average nutrient content is shown in Table 2. After the treatments were implemented the plots at all sites were levelled using an offset disc. Since 2015 only seed and district practice fertiliser rates have been applied to all plots.

In 2018 the Hart sites were sown with narrow points and press wheels on 250 mm spacing. The Bute sites were sown using a concord seeder on 300mm spacing with 150 mm sweep points and press wheels and at Hill River the sites were sown using parallelogram knifepoint and press wheel seeder on 250 mm spacing.

The rate of chicken litter (20 t/ha) used in these trials was based on the rate being used in south western Victoria where the large yield responses had been observed. To assess if responses to chicken litter were attributed directly to the nutrition in the chicken litter, the 3 t/ha synthetic fertiliser treatment was designed to replicate the level of nutrition that is found in an average analysis of 20 t/ha of chicken litter. This treatment was made up of 800 kg/ha mono ammonium phosphate (MAP), 704 kg/ha muriate of potash (MoP), 420 kg/ha sulphate of ammonia (SoA) and 1026 kg/ha urea.

Table 2. Average nutrient concentration from three chicken litter sources used in subsoil manuring trials established in 2015.

Nutrient		Nutrient concentration dry weight	Moisture content	Nutrient concentration fresh weight	Kg nutrient per tonne fresh weight
N	Nitrogen	3.8 %	8%	3.50 %	35.0
P	Phosphorus	1.72 %		1.58 %	15.8
K	Potassium	2.31 %		2.13 %	21.3
S	Sulfur	0.55 %		0.51 %	5.1
Zn	Zinc	0.46 g/kg	8%	0.42 g/kg	0.4
Mn	Manganese	0.51 g/kg		0.47 g/kg	0.5
Cu	Copper	0.13 g/kg		0.12 g/kg	0.1

Measurements in 2018 include grain yield and quality at the Hart and Hill River sites and grain yield and quality at the Bute Mid and NW sites and hay yield at the Bute SE site.

Results

Hill River sites

Canola grain yield at the East site (brown cracking clay) averaged 1.9 t/ha. There were no significant treatment effects.

At the West site (loam over red clay), treatment differences were only significant at the 10% level (Table 2) where there was an 8.5% reduction in grain yield as a result of deep ripping. There was no consistent effect of nutrition, either chicken litter or synthetic fertiliser, on grain yield.

Table 2. Canola grain yield and quality for Hill River West subsoil amelioration trial in 2018.

Treatment	Chicken litter (t/ha)	NPKS	Ripping	Grain yield (t/ha)	Oil (%)	Protein (%)
1	0	No	None	1.97	44.0	20.9
2	0	No	Deep rip	1.84	43.5	22.0
3	20	No	None	1.95	41.5	23.2
4	20	No	Deep rip	1.94	41.9	23.2
5	20	No	Deep rip & place	1.88	41.6	23.2
6	0	3t/ha combo	None	2.07	43.2	21.9
7	0	3t/ha combo	Deep rip	1.71	42.2	22.7
8	0	3t/ha combo	Deep rip & place	1.77	42.4	22.5
LSD (0.10)				0.20	1.5	1.3

Bute sites

In 2018 the Bute NW site was sown to Mulgara oats for a seed crop and the Mid and SE sites were sown to Trojan wheat. Due to frost damage the SE site was cut for hay.

In-season NDVI of the Bute NW site (September) showed a reduction in plots that were deep ripped in 2015, excluding plots treated with chicken litter on the surface. This trend continued to grain yield where all plots that were ripped were lower yielding. Plot yields of treatments applied to the surface or the subsoil were equal.

The Bute Mid site was the highest yielding trial with grain yields ranging from 3.67 to 3.93 t/ha. Green seeker NDVI indicated that there was a significant nutrition response, with the highest values coming from the chicken litter treatments. In this trial ripping did not have an impact on grain yield. Placement of nutrition in the subsoil did result in lower yields than when applied to the surface. As expected, and for other sites, protein was elevated in the nutrition treatments, with chicken litter yield responses being slightly higher than those from the synthetic fertiliser.

Due to frost, the Bute SE site was cut for hay. NDVI in September indicated higher biomass in the chicken litter treatments when applied to the surface with a smaller response from the synthetic fertiliser. Hay yield responses were similar to the NDVI but were less significant.

Table 3. NDVI, Grain yield and quality for the Bute Northwest and Mid subsoil amelioration sites 2018.

Nutrition	Ripping	Placement	Bute NW Oat			Bute Mid Wheat		
			NDVI 5th Sept	Grain yield (t/ha)	Protein (%)	NDVI 5th Sept	Grain yield (t/ha)	Protein (%)
Nil	None	Nil	0.87	2.16	14.2	0.76	3.77	11.5
Nil	Yes	Nil	0.84	1.43	14.4	0.76	3.77	12.2
20 t/ha chic. lit.	None	Nil	0.87	1.66	15.1	0.84	3.87	14.5
20 t/ha chic. lit.	Yes	Surface	0.87	1.17	15.0	0.81	3.90	14.4
20 t/ha chic. lit.	Yes	Subsoil	0.86	1.15	15.3	0.80	3.67	13.9
3 t/ha syn. fert.	None	Nil	0.87	2.03	14.5	0.80	3.93	13.7
3 t/ha syn. fert.	Yes	Surface	0.85	1.45	15.0	0.79	3.77	13.9
3 t/ha syn. fert.	Yes	Subsoil	0.85	1.21	14.9	0.79	3.70	14.2
LSD (0.05)			*0.02*	*0.36*	*0.5*	*0.02*	*0.16*	*0.6*

Table 4. Greenseeker NDVI and hay yield for the Bute south east subsoil amelioration site 2018.

Nutrition	Ripping	Placement	Bute SE Wheat hay	
			NDVI 4th Sept	Hay yield (t/ha)
Nil	None	Nil	0.57	3.4
Nil	Yes	Nil	0.50	3.0
20 t/ha chic. lit.	None	Nil	0.63	3.6
20 t/ha chic. lit.	Yes	Surface	0.60	3.7
20 t/ha chic. lit.	Yes	Subsoil	0.53	3.2
3 t/ha syn. fert.	None	Nil	0.61	3.4
3 t/ha syn. fert.	Yes	Surface	0.56	3.5
3 t/ha syn. fert.	Yes	Subsoil	0.54	3.3
LSD (0.05)			*0.05*	*0.5*

Hart Sites

At the Hart West site, the application of 20 t/ha chicken litter (applied in 2015) resulted in a 34% reduction in barley grain yield when it was applied to the surface (Table 5). When placed in the subsoil the yield reduction was smaller. The synthetic fertiliser applied at the same time did not reduce grain yields. Although protein responses were only significant at the 10% level there is a trend showing plots treated with some form of nutrition had elevated protein. As per the grain yield, retention was reduced when chicken litter was applied to the surface and screenings were elevated. Ripping had little effect on the grain yield or quality at this site.

At the Hart East site, grain yields were lower, averaging 0.54 t/ha, potentially due to the effects of wide spread frost in the region given its lower elevation. However, there were similar levels of yield reduction (45%) when the chicken litter was applied to the surface. As expected, protein was elevated as a result of application of either chicken litter or synthetic fertiliser. Test weight was significantly reduced with the application of chicken litter to the surface. Grain size was generally reduced by application of either amendment.

Table 5. Grain yield and quality for the Hart subsoil amelioration sites 2018.

Nutrition	Ripping	Placement	Hart West				Hart East				
			Grain yield (t/ha)	Protein (%)	Retention (%)	Screenings (%)	Grain yield (t/ha)	Protein (%)	TW (kg/hL)	Retention (%)	Screenings (%)
Nil	None	Nil	1.31	16.7	85.7	1.5	0.83	18.7	62.9	79.0	6.1
Nil	Yes	Nil	1.12	18.2	82.9	2.0	0.75	19.7	61.9	67.2	9.1
20 t/ha chic. lit.	None	Nil	0.86	20.6	76.0	3.0	0.46	20.9	59.4	54.2	13.8
20 t/ha chic. lit.	Yes	Surface	0.76	19.9	74.1	3.3	0.30	22.4	59.4	44.6	17.2
20 t/ha chic. lit.	Yes	Subsoil	1.07	19.3	83.2	1.9	0.55	21.2	62.5	55.4	11.2
3 t/ha syn. fert.	None	Nil	1.08	19.3	83.6	2.0	0.60	20.5	61.3	64.3	9.3
3 t/ha syn. fert.	Yes	Surface	0.98	19.5	82.2	2.3	0.44	21.6	61.8	49.9	12.2
3 t/ha syn. fert.	Yes	Subsoil	1.06	19.1	82.8	2.0	0.39	21.4	61.5	47.1	14.7
LSD (0.05)			*0.30*		*4.0*	*0.8*	*0.19*	*1.3*	*1.4*	*12.7*	*4.2*
LSD (0.10)				*0.20*							

Summary and discussion for 2018

Ripping effects were either not significant or detrimental to yields at all sites. At Hill River there was little impact from the application of either chicken litter or synthetic fertiliser and ripping reduced yield at one site. At the Bute sites, there was a reduction in hay and grain yield at two of three sites as a result of ripping. Hart sites had a greater negative response from chicken litter than the synthetic fertiliser and ripping also resulted in lower yields. These results suggest that the effects of the synthetic fertiliser are diminishing in comparison to the chicken litter. This indicates a slower release and longer lasting effect from the chicken litter, albeit a negative effect in 2018.

Cumulative responses over four years

Given the significant investment in treatments of this nature, it is important to look at the long-term responses from soil amelioration. Figures 1 – 3 show cumulative grain yields for the seven sites from 2015 until 2018. These graphs show that the nutrition response at the Hill River sites in the high yielding season of 2016 caused the main differences in cumulative yield. At these two sites there has been little or no response to ripping or the placement position of the amendment. At other sites (Hart and Bute) most of the responses to ripping or the addition of either amendment have been insignificant or negative when compared to the nil treatment (T1).

Chicken litter effects on lentils

Lentil grain yields at Hart in 2016 and Bute in 2017 were reduced by an average of 29% and 23% respectively in response to chicken litter applied to the surface (Figure 4). This reduction was initially thought to be from high biomass production, resulting in higher levels of disease. However, observations throughout the growing season at Bute indicated similar disease levels throughout all treatments. It is not clear why the synthetic fertiliser applied to the surface did not have the same negative impact as chicken litter.

Deep ripping effects

Although generally not significant over the four years, the response to deep ripping alone was slightly negative at all but the Hill River East site. The large yield reductions in 2015 of up to 72% were a result of poor establishment due to the cloddy seed bed in the first year. However in subsequent seasons, crop establishment was good.

Chicken litter placement effects

Deep placement of chicken litter improved yields at Hart in the dry years of 2015 and 2018 (Figure 6). The deep placement delayed crop access to the amendment and delayed crop response, effectively reducing the canopy size compared to surface placement. This delayed response and interaction with reduced early soil moisture use is thought to explain the response to deep placement. Deep placement of chicken litter also improved yields of lentils at Hart (2016) and Bute (2017) compared with surface application. This was due to surface application negatively effecting lentil yields rather than subsoil placement being positive. At the Hill River sites in 2016, when there was the greatest response to the application of an amendment, the depth of placement was not important (Figure 6). This indicates that the grain yield responses achieved at this site were likely due to increased nutrition and not amelioration of the subsoil.

Chicken litter vs. synthetic fertiliser

Grain and hay yields from synthetic fertiliser treatments applied to the surface have generally been equal or greater than that of the plots treated with chicken litter (Figure 7). The greatest difference in grain yields between these treatments was produced at the Hart West site and was 1.0 t/ha or 40%. This occurred in the lentil phase and can be attributed to yield reductions from chicken litter rather than yield increases from synthetic feritilser. A similar effect occurred at the Bute sites in 2017. Other increases in grain yield from synthetic fertiliser compared to chicken litter may be attributed to; poorer emergence at Hart in 2015 as a result of toxic levels of fertiliser being applied to the surface resulting in reduced canopy and retained soil moisture for the end of the season. Because of the low yields at the Hart sites in 2018, the large relative differences are only 0.23 and 0.24 t/ha for the East and West sites respectively.

Figure 7 is a photograph of a soil pit at the Hart West site showing how the 20 t/ha chicken litter appears to have changed little from when it was placed there in 2015. This also indicates that there has been little amelioration of the subsoil. Soil pits at other sites have not been excavated.

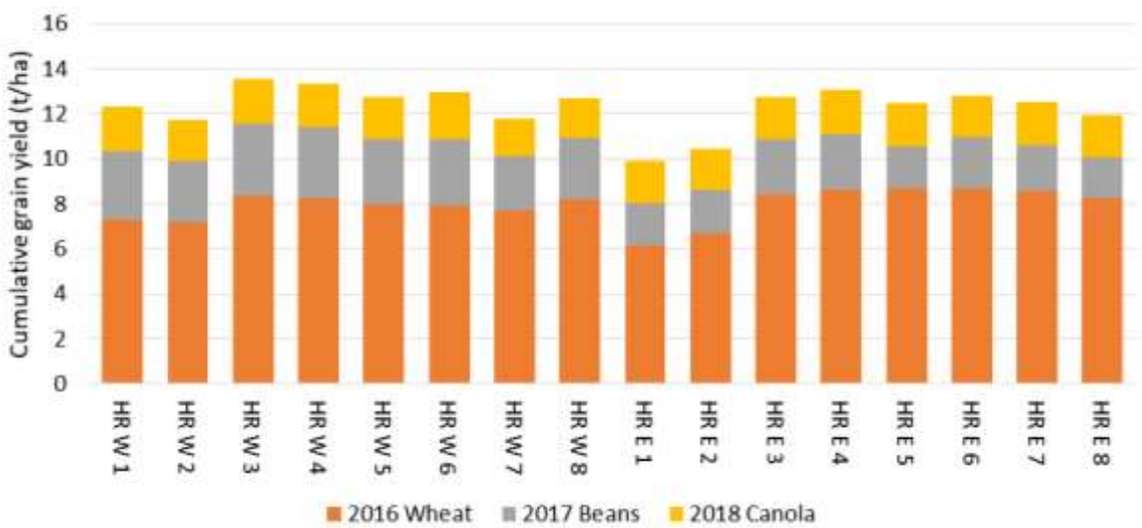

Figure 1. Cumulative grain yield (t/ha) for the Hill River subsoil amelioration sites from 2016 to 2018. LSD (0.05) for Hill River West (HR W) = 0.9 and Hill River East (HR E) = 0.9. For treatments see Table 1.

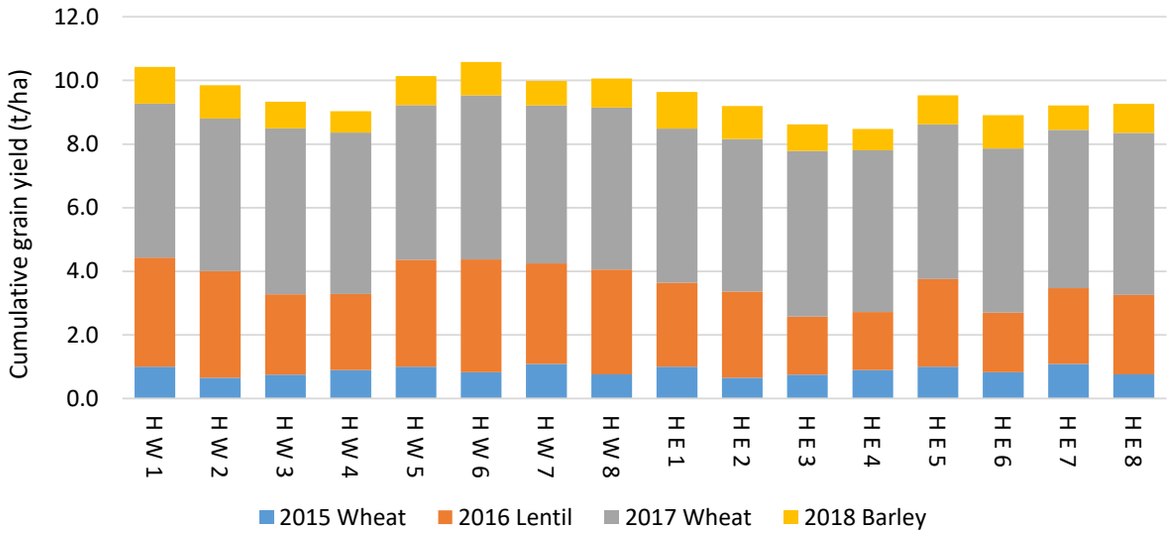

Figure 2. Cumulative grain yield (t/ha) for the Hart subsoil amelioration sites from 2015 to 2018. LSD (0.05) for Hart West (H W) = 0.9 and Hart East (H E) = 0.7. For treatments see Table 1.

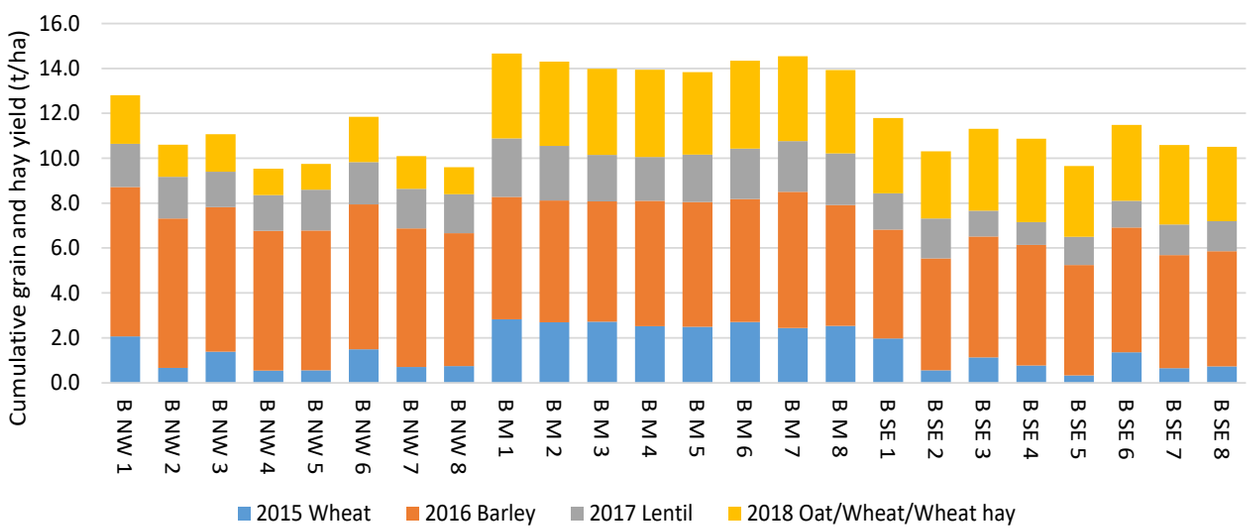

Figure 3. Cumulative grain and hay yield (t/ha) for the Bute subsoil amelioration sites from 2015 to 2018. In 2018 NW was oats, Mid was wheat and SE was wheat hay. LSD (0.05) for Bute north west (B NW) = 0.7, LSD (0.10) for Bute mid (B M) = 0.7 and Bute south east (B SE) = 0.7. For treatments see Table 1.

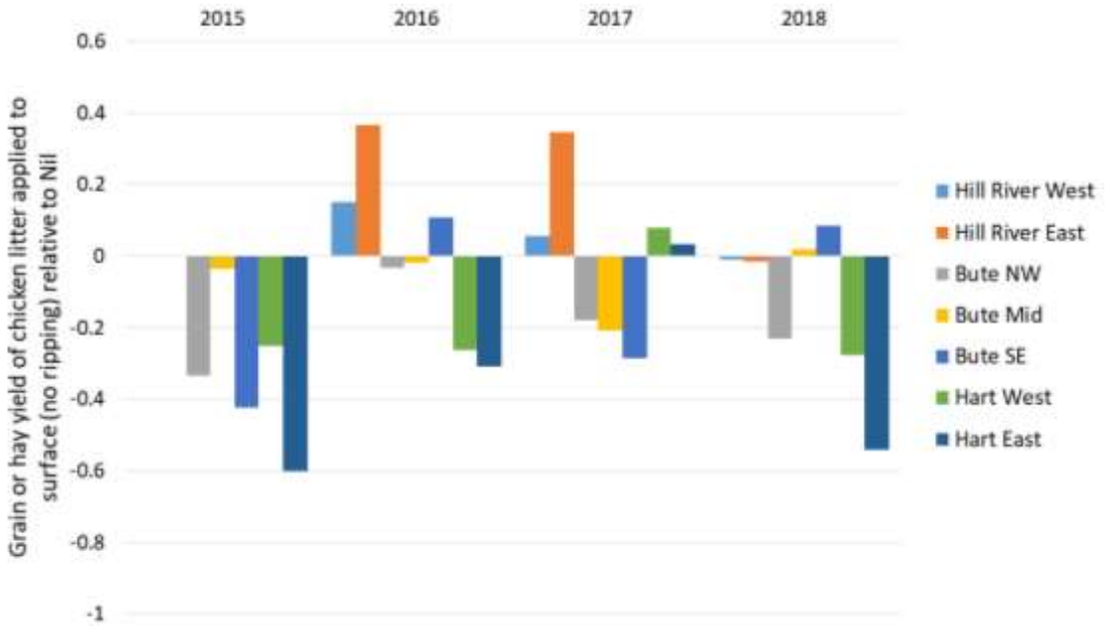

Figure 4. Grain and hay yield response of surface applied chicken litter (20 t/ha) relative to the nil treatment for subsoil manuring sites 2015 – 2018.

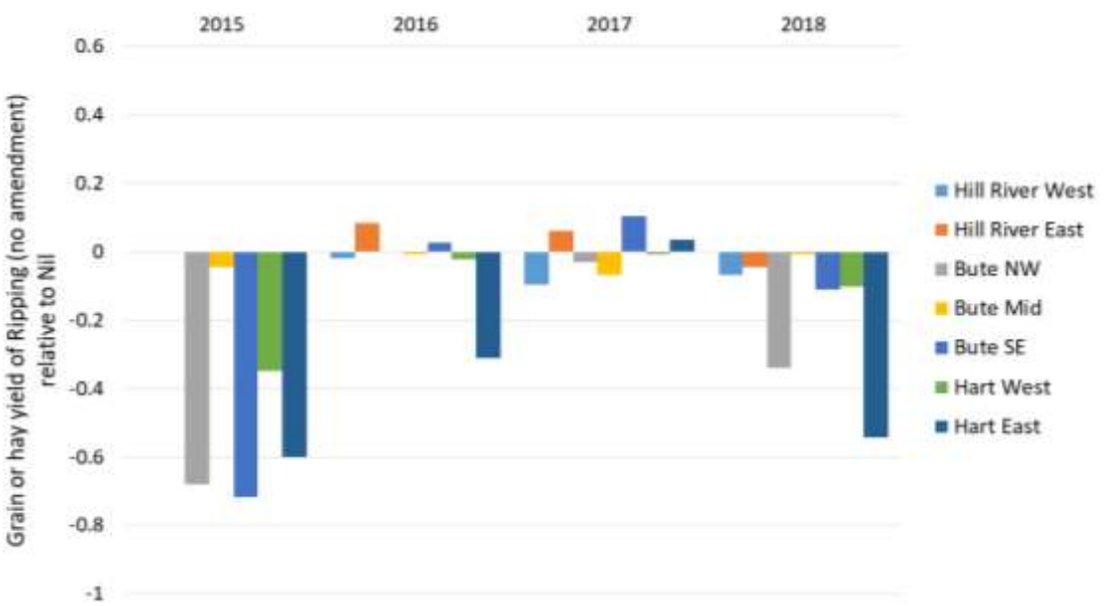

Figure 5. Grain and hay yield response to ripping in the absence of an ameliorant relative to the nil treatment for subsoil manuring sites 2015 – 2018.

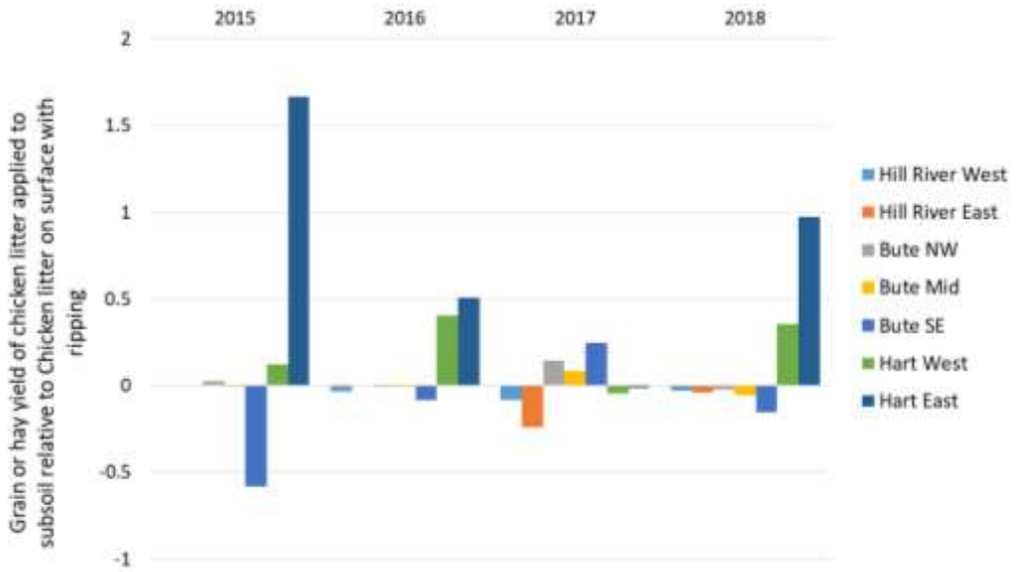

Figure 6. Grain and hay yield response to placing 20 t/ha of chicken litter in the subsoil relative to the placing 20 t/ha chicken litter on the surface for subsoil manuring sites 2015 – 2018.

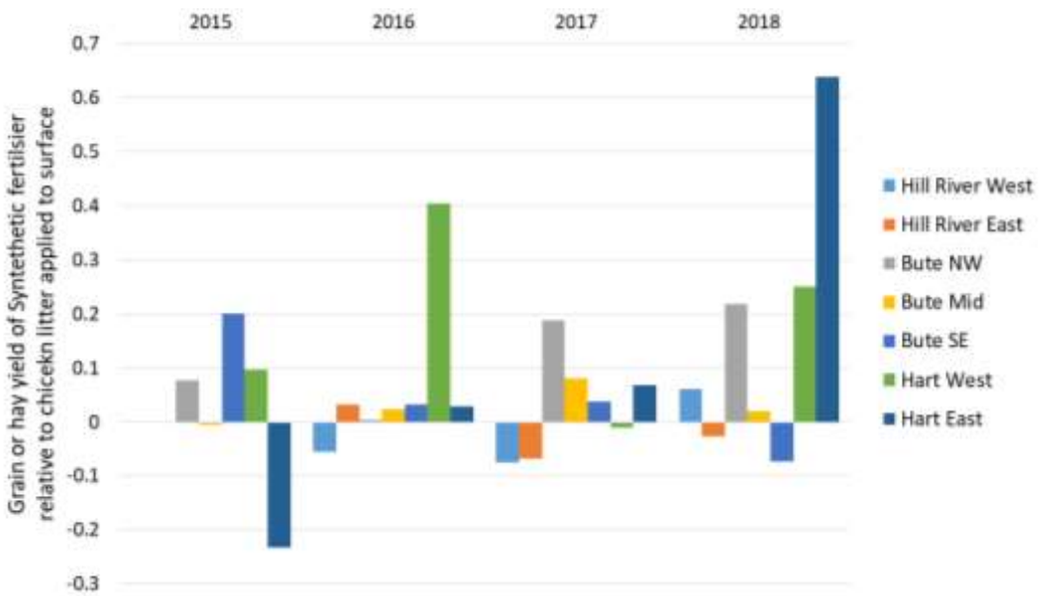

Figure 7. Grain and hay yield response of 3 t/ha of synthetic fertiliser applied to the surface relative to applying 20 t/ha of chicken litter to the surface, with no ripping, for subsoil manuring sites 2015 – 2018.

Figure 7. Subsoil applied chicken litter (20 t/ha) at the Hart West site. Photo taken on October 2018, after three years and seven months in the soil.

Summary / implications

Subsoil amelioration using the method of ripping chicken litter or synthetic fertiliser into the subsoil has not led to increased grain yields at any of the seven sites set up in 2015. In most cases the ripping process required to place the amendment into the subsoil caused significant soil disturbance and resulted in reduced grain yields. The amendment itself applied either to the surface or at depth did increase yields significantly in the high yielding season of 2016 at the Hill River sites, but other than that most responses have been neutral or negative. Given these results undertaking these treatments on these soil types on a paddock scale is not recommended.

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