GRDC SANDY SOILS (CSP00203)

PIRSA SITES RESULTS SUMMARY

PRIMARY INDUSTRIES & REGIONS SA
PIRSA

Background

In 2014 the South Australian Government launched the 'New Horizons' soil improvement program which focussed on overcoming constraints on sandy soils. Trial sites were established in the Eyre Peninsula, Murray Mallee and South East; at Brimpton Lake, Karoonda and Cadgee respectively. The program aimed to achieve a significant increase in productivity and profitability – more specifically, a doubling in yield.

A range of treatments were applied to ameliorate constraints to production commonly found on sandy soils including compaction, water repellence, low water holding capacity and poor fertility. The impact of the treatments on crop production was monitored by PIRSA in 2014 and 2015 and the trials were then incorporated into the GRDC Sandy Soils project in 2016. They will continue to be monitored in this project during 2017 and 2018.

Method

Treatments included the incorporation of clay, fertiliser or organic matter (OM), alone or in combination. They were applied in 2014 and have not been reapplied (Table 1).

Soil fertility was assessed after treatment application and mineral nitrogen and moisture have been monitored pre-sowing in each year.

The sites have been cropped annually (Table 2) with additional nutrients applied each season to meet crop requirements. Crop establishment, biomass, grain production and grain quality have been assessed.

Table 1. Treatments applied in March 2014

Unmodified Control: managed as district practice
Deep Nutrition: fertiliser banded to 30 cm
Shallow Clay: disced to 10 cm
Shallow Clay + Deep Nutrition
Spading: to 30 cm
Spading + Nutrition: fertiliser spaded in
Spading + Clay: clay spaded in
Spading + Clay + Nutrition
Spading + OM: lucerne hay or pellets spaded in
Spading + OM + Nutrition
Spading + Clay + OM
Spading + Clay + OM + Nutrition

Unmodified Control
Karoonda 2014

Table 2. Crop and rainfall data for the three sites.

Year	Crop sown	Annual rainfall (mm)	In-crop rainfall (mm)
Brimpton Lake: average annual 465 mm			
2014	Corack wheat	445	345
2015	Emu Rock wheat	350	305
2016	Spartacus barley	562	425
Karoonda: average annual 340 mm			
2014	Grenade wheat	305	175
2015	Scout wheat	290	135
2016	Gunyah peas	582	375
Cadgee: average annual 540 mm			
2014	Grenade wheat	350	280
2015	Scope barley	280	205
2016	Canola 559TT	649	538

S+C+OM+Nut
Karoonda 2014

Results: Brimpton Lake

Principal soil constraints at the site:

- severe water repellence
- moderate nutrient fertility
- low organic carbon
- high bulk density
- low nutrient and water holding capacity

OM was applied as lucerne hay at 10 t/ha and the average clay material application rate was 450 t/ha. Table 3 summarises the impact of two key treatments on soil properties relative to the control, showing

- The addition of OM increased mineral nitrogen in the soil by > 50 kg/ha in 2014. Since this time, pre-sowing mineral nitrogen reserves have depleted in the OM treatments, though crop responses are still observed.
- The addition of clay increased the pH, cation exchange capacity (CEC) and clay % in the top 30 cm and reduced water repellence.
- Spading the soil reduced bulk density in the top 30 cm and only moderately reduced water repellence.

Photo of the soil profile in a spaded treatment at Brimpton Lake; note the mixing of the grey topsoil throughout the infertile bleached horizon below which extends to 25-50 cm. The B horizon is sodic and contains 35-45 % clay.

Table 3. Soil properties for three of the key treatments at the Brimpton Lake site in 2014, three weeks after the treatments were applied and incorporated.

Treatment	Depth cm	Chemical				Physical	Hydrological	
		pH $CaCl_2$	OC %	CEC cmol + /kg	Mineral N kg/ha	Bulk density g/cm^3	Water repellence (MED)	Clay content %
Control	0 -10	5.6	0.50	3.1	14	1.53	Severe	4
	10 -20	5.9	0.31	1.6	10	1.69	N/A	3
	20 -30	6.0	0.14	1.7	9	1.71	N/A	3
	30 -50	6.5	0.23	9	16	1.62	N/A	25
S + OM	0 -10	6.0	-	2.2	41	1.51	Moderate	4
	10 -20	5.9	-	2.3	36	1.58	N/A	4
	20 -30	5.6	-	1.6	21	1.62	N/A	4
	30 -50	6.1	-	9.4	20	1.65	N/A	29
S + C	0 -10	6.6	-	4.8	7	1.46	Very low	10
	10 -20	6.8	-	6.3	19	1.58	N/A	9
	20 -30	6.2	-	2.4	12	1.56	N/A	5
	30 -50	6.1	-	8.4	13	1.64	N/A	25

Crop responses

- Crop responses were affected by early season waterlogging in 2014 and 2016 and by dry, hot and windy spring conditions in 2014 and 2015.
- Water repellence was not expressed in any of these three years, with relatively uniform establishment across all treatments (Table 4).
- Yields in the unmodified control were typical of those obtained on poorly productive sands in the district.
- Deep incorporation of clay by spading generally produced better crops than shallow incorporated clay.
- Incorporating OM initially increased N fertility, reduced water repellence and resulted in the highest grain yields at the site in 2014 and 2015.
- Combining spading, clay, OM and nutrition produced the highest dry matter at flowering in 2014 and 2015, and produced high grain yields, but not always the highest, in those years.
- Crop responses were enhanced in low rainfall years; little or no crop response was observed in 2016 when rainfall was above average.
- S+OM has produced the highest cumulative grain yield to date, equating to 3.66 t/ha above that of the unmodified control over three years.

Table 4. Crop production; 2014 wheat, 2015 wheat, 2016 barley. The figures in BOLD were significantly different to the unmodified control (5% LSD).

	Established plants /m^2			Dry Matter at flowering t/ha			Grain Yield t/ha		
Treatment	2014	2015	2016	2014	2015	2016	2014	2015	2016
unmodified control	181	140	161	1.03	3.53	4.41	1.40	1.89	3.63
deep nutrition	185	131	154	1.54	3.93	4.13	**1.86**	2.18	3.44
shallow clay	156	140	168	1.50	4.59	4.81	**2.01**	**2.75**	3.74
shallow clay + deep nutrition	153	132	160	**1.63**	3.48	4.46	1.51	2.05	3.71
spading	171	140	157	1.14	3.73	4.38	**2.29**	**2.71**	3.67
spading + nutrition	178	144	154	0.91	4.22	3.82	1.56	**2.68**	3.22
spading + clay	164	147	161	1.33	4.04	5.60	**2.48**	**2.85**	3.97
spading + clay + nutrition	167	134	162	1.33	4.02	5.20	1.69	**2.48**	3.90
spading + OM	181	137	175	**2.54**	**5.78**	4.90	**2.96**	**3.69**	3.94
spading + OM + nutrition	160	140	165	**1.96**	**6.02**	4.35	**2.85**	**3.82**	3.91
spading + clay + OM	164	143	170	**2.32**	**5.72**	4.22	**2.62**	**3.42**	3.63
spading + clay + OM + nutrition	175	144	169	**2.63**	**6.30**	4.50	**2.81**	**3.38**	4.01

Results: Karoonda

Principal soil constraints at the site:

- severe water repellence
- low nutrient fertility
- very low organic carbon
- low water holding capacity
- high bulk density and high soil strength.

OM was applied as lucerne pellets at 10 t/ha and the average clay material application rate was 600 t/ha. Table 5 summarises the impact of two key treatments on soil properties relative to the control, showing:

- The addition of OM substantially increased soil mineral nitrogen (>180 kg/ha) in the soil in 2014. Pre-sowing N concentration is decreasing slowly with time, though crop responses are still observed.
- The addition of clay increased pH, cation exchange capacity (CEC) and clay % in the top 30 cm and reduced water repellence.
- Spading reduced bulk density in the top 30 cm and reduced water repellence initially.

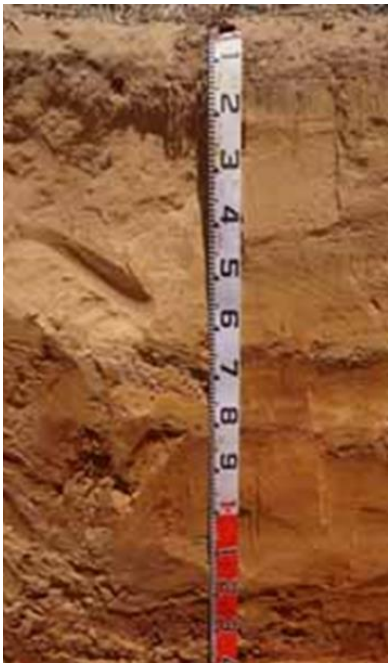

Photo of the soil profile at Karoonda, comprising grey shallow sand grading to an orange leached sandy layer which overlies an orange brown clay (20-30% clay) 60 cm below the soil surface

Table 5. Initial soil properties for three of the key treatments at Karoonda.

Treatment	Depth cm	Chemical				Physical	Hydrological	
		pH $CaCl_2$	OC %	CEC cmol+ /kg	Mineral N kg/ha	Bulk density g/cm^3	Water repellence (MED)	Clay content %
Control	0 -10	6.5	0.43	3.4	24	1.52	Severe	4
	10 -20	6.7	0.18	2.6	12	1.65	N/A	4
	20 -30	7.0	0.49	2.7	8	1.61	N/A	4
	30 -50	7.4	0.07	6.4	13	1.65	N/A	12
S + OM	0 -10	6.9	-	3.9	127	1.37	Very Low	4
	10 -20	6.8	-	3.0	74	1.48	N/A	4
	20 -30	7.0	-	3.3	24	1.57	N/A	6
	30 -50	7.5	-	7.4	13	1.62	N/A	15
S + C	0 -10	7.2	-	5.7	13	1.42	Very low	10
	10 -20	6.8	-	3.8	18	1.53	N/A	6
	20 -30	6.8	-	3.5	13	1.58	N/A	10
	30 -50	7.3	-	5.1	10	1.62	N/A	7

Crop responses

- Control yields were typical of those obtained on poorly productive sands in the district but were further affected by severe frosts in 2014 and 2015 and by hail in 2016.
- In 2015, water repellence severely affected crop establishment (Table 6) but spading in clay or OM overcame this constraint.
- Deep nutrition increased crop performance which may be a combination of reduced soil strength and/or improved nutrition.
- Poorly incorporated shallow clay initially reduced establishment and did not improve crop performance.
- Incorporating OM +/- clay increased N fertility, overcame water repellence and resulted in the highest grain yields at the site.
- Combining spading, clay, OM and nutrition produced the highest biomass of all treatments but only resulted in the highest grain yield in 2016. Nonetheless, it has produced the highest cumulative grain yield increase of 3.05 t/ha above the unmodified control.
- Crop response to incorporated clay is improving with time.

Table 6. Crop production; 2014 wheat, 2015 wheat, 2016 peas. The yields in BOLD were significantly different to the unmodified control (5% LSD).

	Established plants /m^2			Dry Matter at Flowering t ha^{-1}			Grain Yield t ha^{-1}		
Treatment	2014	2015	2016	2014	2015	2016	2014	2015	2016
unmodified control	121	72	30	0.75	1.65	1.22	0.49	0.48	1.86
deep nutrition	110	65	30	**1.10**	1.73	1.38	**1.57**	**0.95**	2.29
shallow clay	**58**	62	32	0.72	1.28	1.15	0.38	0.31	1.40
shallow clay + deep nutrition	**65**	**50**	31	**1.04**	1.87	1.18	**1.44**	**1.04**	1.86
spading	113	71	31	**1.21**	2.14	1.37	**1.47**	**0.95**	2.37
spading + nutrition	105	66	30	**1.64**	**2.40**	1.35	**1.14**	0.63	1.68
spading + clay	115	**101**	32	**1.48**	**2.65**	1.59	**1.07**	**0.88**	2.19
spading + clay + nutrition	112	**101**	35	**1.76**	**3.06**	1.45	**1.05**	0.69	2.35
spading + OM	104	**102**	28	**2.02**	**2.66**	1.57	**2.05**	**1.45**	2.16
spading + OM + nutrition	117	**97**	29	**2.41**	**2.50**	1.28	**2.00**	**1.44**	2.08
spading + clay + OM	117	**109**	33	**1.96**	**3.16**	**1.72**	**1.57**	**1.55**	2.39
spading + clay + OM + nutrition	113	**108**	32	**2.08**	**3.69**	**1.91**	**1.42**	**1.49**	**2.97**

Results: Cadgee

Principal soil constraints at the site:

- very severe water repellence
- low soil pH and high exchangeable aluminium
- very low nutrient fertility
- low organic carbon
- low nutrient and water holding capacity.

OM was applied as lucerne hay at 10 t/ha and the average clay material application rate was 500 t/ha. Table 7 summarises the impact of two key treatments on soil properties relative to the control, showing:

- The addition of OM increased soil mineral nitrogen by more than 100 kg/ha pre-sowing in 2014, but did not reduce water repellence, which is in contrast to other sites.
- The addition of clay increased cation exchange capacity (CEC) and clay % in the top 30 cm and significantly reduced water repellence.
- Soil pH was only moderately affected by the treatments; lime was applied to the site in 2015 to ameliorate acidity.

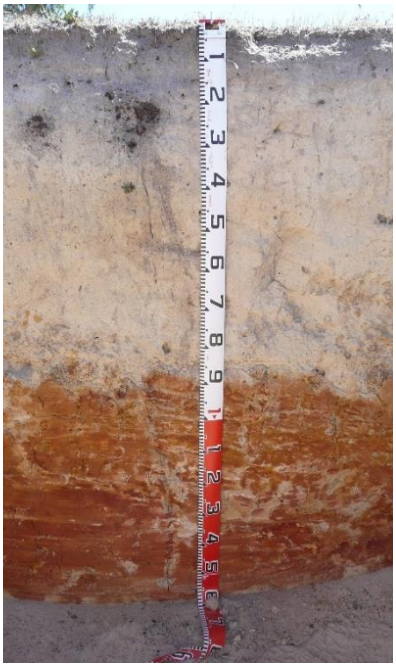

Photo of the soil profile at the Cadgee site, showing a shallow A1 horizon of grey sand, overlying a very deep infertile, acidic, bleached white sand, with B horizon clay generally intercepted below 90 cm.

Table 7. Soil properties for three of the key treatments at the Cadgee site, measured in 2014.

Treatment	Depth cm	Chemical				Physical	Hydrological	
		pH CaCl2	OC %	CEC cmol+ /kg	Mineral N kg/ha	Bulk density g/cm^3	Water repellence (MED)	Clay content %
Control	0 -10	4.8	0.89	2.8	26	1.35	Very severe	4
	10 -20	4.4	0.43	1.1	11	1.33	N/A	4
	20 -30	4.5	0.25	0.6	7	1.37	N/A	4
	30 -50	4.9	0.11	2.7	8	1.41	N/A	4
S + OM	0 -10	5.5	-	2.9	116	1.34	Very severe	2
	10 -20	4.5	-	1.3	43	1.40	N/A	2
	20 -30	4.2	-	0.6	12	1.46	N/A	3
	30 -50	4.5	-	0.7	15	1.51	N/A	2
S + C +OM + Nut	0 -10	5.1	-	3.7	102	1.30	Very low	7
	10 -20	4.9	-	1.8	32	1.35	N/A	4
	20 -30	4.1	-	0.7	11	1.43	N/A	1
	30 -50	4.8	-	1.5	12	1.45	N/A	1

Crop responses

- Crop responses were constrained in 2014 and 2015 by well below average rainfall, frost and dry windy spring conditions.
- Higher than average rainfall was received in 2016, but the crop was badly damaged by birds at maturity and was not harvested.
- Both shallow clay and spaded clay only treatments performed well at this site and improved with time (Table 8).
- Both the deep nutrition and spaded nutrition treatments performed well in 2014, but the response is substantially declining with time.
- Incorporating OM significantly improved crop performance compared to the unmodified control.
- Combining spading, clay, OM and nutrition produced the highest biomass of all treatments in 2014 and 2015 and produced the highest grain yield in 2015, obtaining the highest cumulative grain yield increase of 1.4 t/ha above the control (2 seasons only).

Table 8. Crop production; 2014 wheat, 2015 barley, 2016 canola (not harvested). The yields in BOLD were significantly different to the unmodified control (5% LSD).

	Established plants /m^2			Dry Matter at Flowering t/ha			Grain Yield t/ha		
Treatment	2014	2015	2016	2014	2015	2016	2014	2015	2016
unmodified control	74	72	58	0.77	3.04	1.28	0.59	1.27	NA
deep nutrition	95	**45**	51	0.89	2.80	1.47	**0.90**	0.95	NA
shallow clay	**115**	**107**	62	0.94	**3.90**	**2.30**	0.53	1.44	NA
shallow clay + deep nutrition	91	**102**	56	0.78	3.52	**2.37**	0.67	1.26	NA
spading	**135**	**46**	**43**	**1.15**	2.98	1.06	**1.00**	1.03	NA
spading + nutrition	**127**	**55**	**32**	**1.40**	2.54	1.14	**1.38**	**0.87**	NA
spading + clay	**165**	**97**	51	**1.25**	**4.05**	**2.03**	**0.84**	1.63	NA
spading + clay + nutrition	**160**	**94**	47	**1.19**	**3.91**	**1.99**	0.75	1.60	NA
spading + OM	**121**	**87**	54	**1.87**	3.42	1.54	**1.19**	**1.84**	NA
spading + OM + nutrition	**117**	**89**	50	**1.73**	3.21	1.33	**1.23**	1.65	NA
spading + clay + OM	**155**	**109**	55	**1.99**	**4.31**	**2.25**	**1.00**	**2.12**	NA
spading + clay + OM + nutrition	**146**	**110**	**41**	**2.23**	**4.85**	**2.17**	**1.06**	**2.20**	NA

Key messages:

- Crop grain yields were often doubled in 2014 and 2015 for treatments that address the key constraints at each site.
- Spading + Clay + OM + Nutrients often delivered the highest biomass, but this did not always convert through to the highest grain yield.
- In the first two years, spading and OM had the biggest impact on crop performance
- Clay application has increased cation exchange capacity and overcome water repellence at the soil surface; the type of incorporation influences the depths that were improved.
- Clay application did not increase yields in the first two years but may be having a greater influence in later years.
- At sites where bulk density was high, spading reduced it to less than 1.6 g/cm^3 and higher yields resulted.
- Deep nutrition at Karoonda has shown consistent increases in grain yield, which is in contrast to other sites.
- Extensive characterisation of the soil chemical, physical, biological and hydrological condition will be conducted in 2018, enabling the cause of the crop production gains to be quantified.

We acknowledge the assistance and contribution of the Moroney, Roberts and Price families, the farmer co-operators at the sites.

Project Contact:
Melissa Fraser
Senior Consultant Soils
Rural Solutions South Australia, PIRSA
Phone: 0427 084 569
Email: melissa.fraser@sa.gov.au

This work is funded under the GRDC project "Increasing production on Sandy Soils in low and medium rainfall areas of the Southern region" (CSP00203); a collaboration between the CSIRO, the University of South Australia, the SA state government through Primary Industries and Regions SA, Mallee Sustainable Farming Inc. and AgGrow Agronomy.