# Management options for dry saline soils on Upper Yorke Peninsula: results from three seasons

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**Key findings**

- In season one, lentil grain yields were generally low (0.16-0.62 t/ha) across the trial. The high sand application rate (1300 t/ha) was the only treatment to improve lentil grain yield compared to the control.
- In seasons two and three, larger increases in crop emergence, NDVI and grain yield emerged among the sand and straw rates. Specifically, sand rates above 650 t/ha and straw rates above 6.6 t/ha resulted in the highest wheat and barley grain yields.
- Two years after the trial was implemented, all sand and straw application rates reduced the salinity level (ECe and TDS) in both the 0-10 cm and 10-20 cm depths.
- In general, the results show three years after application, the straw and sand rates are having a positive impact on both cumulative grain yield and partial gross margin (despite the high initial amelioration costs).

**Background**

Dry saline soils are a type of land salinity that occurs in soils with high levels of naturally occurring salt (but is not associated with a shallow water table). In mild situations, dry saline land can also be referred to as transient salinity, where salts are trapped within the soil profile (e.g. due to low permeability clay subsoil) and salts move up and down depending on seasonal conditions. Situations which lead to higher evaporation of moisture e.g. long hot summers, periods of drought and the loss of surface plant or stubble cover increase the presence and severity of saline soil patches. Poor plant growth and yields are commonly observed on impacted areas due to the difficulties for crops to take up water in saline soils and the toxic effects of high salt in the plant.

This research aims to trial and demonstrate different management practices which could be used by growers to ameliorate saline soil patches. The application of amendments (e.g. straw and sand) to the soil surface were trialed to improve crop emergence by reducing evaporation leading to reduced accumulation of salt in the topsoil, more soil moisture, or by reducing the moisture required to germinate a seed by increasing the sand content of the soil surface. Gypsum was also included to increase the amount of calcium relative to the level of sodium (salt) and address sodicity in the longer term.

## Methodology

*Site selection and rainfall*

An amelioration trial for the management of saline soils was established at Tickera, SA (-33.8466, 137.6844) in 2022. The saline area was selected based on historical crop performance and soil test results (Table 1). The trial was a randomised complete block design with four replicates and eight treatments that are described below (Table 3). All plots were scored prior to seeding in 2022 for stubble cover (barley) to assess the variation in salinity level across the site. Stubble cover was measured visually by scoring each plot from 1 (low stubble cover = more saline) to 5 (high stubble cover = less saline).

*Soil properties*

Soil samples were collected on April 29, 2022 by sampling the surface 0-10 cm in all five stubble cover scores (Table 1). These scores were used as a covariate in the statistical analysis of the experiment. Deeper cores were sampled in areas with scores 1 and 4 and segmented as follows, 0-10 cm, 10-20 cm, 20-40 cm and 40-60 cm, these were not replicated.

The Tickera site is a moderate to strongly alkaline (pH >8.0) clay loam with salinity issues (Table 1). Salinity was measured using chloride and an electrical conductivity estimated (ECe) which uses a texture conversion factor (9.5 for sandy loam) from the EC1:5. Chloride levels in the surface and subsurface ranged from 520-4800 mg/kg. The critical level for chloride in clay soils is 300 mg/kg (Hughes 2020). Above this critical value salinity damage is likely to occur depending on crop tolerance. The ECe across the site was 5.9-37. In general, it is expected at ECe 4-8 yields of many crops will be affected and 8-16 only crops with tolerance will yield well (Hughes 2020). Beyond 32 is generally considered too salty for most broadacre crops to grow.

Boron levels across the site and soil depths ranged from 8-38 mg/kg. Boron toxicity for sensitive crops generally occurs at levels >5 mg/kg and at levels >15 mg/kg it is considered toxic for dryland cereals (Hughes 2020).

*Table 1. Soil properties for samples collected at salinity management trial Tickera, SA 2022.*

| Stubble cover score | Sample depth | pH 1:5 water | Chloride | Salinity $EC_{1:5}$ (soil:water) | $EC_e$ (estimated) | Boron |
|---|---|---|---|---|---|---|
| | cm | | mg/kg | dS/m | dS/m | mg/kg |
| 1 (Low stubble / more saline) | 0-10 | 8.1 | 4800 | 3.9 | 37 | - |
| | 10-20 | 8.6 | 1500 | 1.5 | 14 | 18 |
| | 20-40 | 8.9 | 1400 | 1.4 | 13 | 29 |
| | 40-60 | 9.1 | 1400 | 1.5 | 14 | 32 |
| 2 | 0-10 | 8.2 | 1800 | 1.6 | 15 | - |
| 3 | 0-10 | 8.2 | 1300 | 1.2 | 11 | - |
| 4 (High stubble / less saline) | 0-10 | 8.0 | 1600 | 1.4 | 13 | - |
| | 10-20 | 8.8 | 520 | 0.62 | 5.9 | 8 |
| | 20-40 | 9.1 | 770 | 0.97 | 9.2 | 25 |
| | 40-60 | 9.1 | 1400 | 1.5 | 14 | 38 |
| 5 | 0-10 | 8.2 | 720 | 0.71 | 6.7 | - |

*Trial details*

Sand and gypsum treatments were spread on the soil surface May 3, 2022. Straw treatments (from baled wheat) were applied post seeding on May 27, 2022. Treatments included; control, gypsum 10 t/ha, straw 3.3 t/ha, straw 6.6 t/ha, straw 10 t/ha, sand 130 t/ha, sand 650 t/ha and sand 1300 t/ha. Sand rates were calculated on applying a sand layer of 1 cm (130 t/ha), 5 cm (650 t/ha) and 10 cm (1300 t/ha) covering the surface. The sand was sourced from a sand pit 15 km northeast of the trial site at Alford and applied using a front-end loader and shovel. The gypsum used in the trial had a purity of 69% making it a grade three product.

*Table 2. Summary of rainfall and seeding details from 2022-2024.*
** Long-term average growing season rainfall for Tickera is 252 mm.*

| Year | Growing season rainfall* | Seeding date | Crop and seeding rate | Fertiliser at seeding |
|---|---|---|---|---|
| 2022 | 250 mm | May 26 | Hurricane XT lentils @ 50 kg/ha | MAP 1%Zn 60 kg/ha |
| 2023 | 219 mm | May 11 | Chief CL Plus wheat @ 80 kg/ha | MAP 65 kg/ha + urea 42 kg/ha |
| 2024 | 146 mm | May 10 | Commodus CL barley @ 80 kg/ha | MAP 1%Zn 60 kg/ha + urea 100 kg/ha |

**Soil and crop assessments 2024**

Pre-seeding all plots were soil cored 0-10 cm, 10-20 cm and 20-40 cm from the original soil surface. Soil samples were analysed for total dissolved solids (TDS) and ECe (as per method above). The high application rates of sand (650 t/ha and 1300 t/ha) created a new soil layer and an additional soil sampling increment was added 'sand' which represents the layer above the original soil surface. The control and gypsum treatment soil samples were also analysed for exchangeable sodium percentage (ESP).

Plant establishment was scored on May 31 and July 9, Greenseeker NDVI on July 12 and September 11. All plots were harvested for grain yield and quality on November 8.

*Statistical analysis*

Analysis of this experiment was conducted using linear mixed models with restricted maximum likelihood using ASReml-R (Butler, 2022) and the R Core Team (2022) package biometryassist (Nielsen et al. 2022). Where there is significant evidence from the model that the explanatory variable means differ, Tukey's multiple comparison test was used to determine which of the means are different at a significance level of 5%.

**Year one and two results**

In season one lentil grain yields were generally low (0.16-0.62 t/ha) across the trial. The high sand application rate (1300 t/ha) was the only treatment to improve lentil grain yield compared to the control (Table 3). In the second season larger differences among the sand and straw rates were emerging. Sand rates above 650 t/ha and straw rates above 6.6 t/ha resulted in wheat grain yields of 1.95-2.42 t/ha compared to the control 0.67 t/ha.

## Year three results

*Changes in soil properties*

Soil salinity can be measured using both ECe and TDS. The average ECe across the site 0-10 cm was 16.5 prior to trial establishment. Without any amelioration, the current control ECe was 18.1 (Table 3) and it is expected only salt tolerant crop types will yield well in these areas. The salinity level (ECe) in all the sand and straw application rates has been reduced, on average by 58% and 33% in the 0-10 cm and 10-20 cm depths, respectively. Overall, it has lowered ECe to an average of 7.6 in both of these layers. This reduction in salinity has also lowered the effect on plant growth to the category 'yield of many crops effected' from 'only tolerant crops yield well' prior to treatment (Hughes 2020).

Total dissolved solids (TDS) is a measure of the total salt content in a given soil or water sample. Similar to the ECe results, any application rate of sand or straw has reduced TDS compared to the control in both the 0-10 cm and 10-20 cm layer (Table 3).

In the 20-40cm layer the analysis using the linear mixed model identified the overall treatment as a significant effect for both ECe and TDS with all sand and straw treatments trending down for ECe and some variation in TDS. However, as Tukey's multiple comparison test is conservative it was unable to identify the pairwise differences between individual treatments.

The ESP identifies the degree to which the soil exchange complex is saturated with sodium and is used to characterise sodicity. ESP was measured in the control and gypsum treatment. It showed a reduction in sodicity in 0-10 cm layer from 17.3 (control) to 12.5 (gypsum) where gypsum was applied (data not shown). This reduction in ESP reduced the soil from >15% 'strongly sodic' down to a 'sodic' classification (Huges 2020). No changes in the ESP for the 10-20 cm and 20-40 cm layer were observed. However, the results also show the application of gypsum has had no effect on salinity (Table 3). This treatment was imposed to address sodicity at this site in the longer term.

*Table 3. Pre-seeding $EC_e$ and TDS for treatments in the salinity management trial Tickera, SA 2024.*

| **Treatment** | **ECe** | | | **TDS (mg/L)** | | |
|---|---|---|---|---|---|---|
| | 0-10 cm | 10-20 cm | 20-40 cm | 0-10 cm | 10-20 cm | 20-40 cm |
| Control | 18.1[a] | 11.4[a] | 15.2[a] | 1235[a] | 807[a] | 993[a] |
| Sand @ 130 t/ha | 8.6[b] | 8.6[b] | 12.4[a] | 598[b] | 592[b] | 820[a] |
| Sand @ 650 t/ha | 6.7[b] | 8.6[b] | 14.3[a] | 450[b] | 581[b] | 948[a] |
| Sand @ 1300 t/ha | 5.7[b] | 7.6[b] | 13.3[a] | 355[b] | 511[b] | 898[a] |
| Straw @ 3.3 t/ha | 8.6[b] | 6.7[b] | 10.5[a] | 575[b] | 474[b] | 720[a] |
| Straw @ 6.6 t/ha | 9.5[b] | 7.6[b] | 10.5[a] | 615[b] | 498[b] | 695[a] |
| Straw @ 10 t/ha | 6.7[b] | 6.7[b] | 10.5[a] | 450[b] | 473[b] | 708[a] |
| Gypsum @ 10 t/ha | 15.2[a] | 12.4[a] | 15.2[a] | 1035[a] | 836[a] | 1005[a] |
| | | | | | | |
| **P-value** | **<0.001** | **<0.001** | **0.001** | **<0.001** | **<0.001** | **0.003** |

*Crop establishment and biomass*

Despite dry conditions pre and post seeding, there were differences observed in crop establishment at the end of May (three weeks after seeding). Both the higher rates of sand (650 t/ha and 1300 t/ha) and the high rate of straw (10 t/ha) had more plants emerged compared to the control (Table 4). The higher plant establishment can be attributed to the retention of more soil moisture under the sand and straw treatments due to reduced evaporation and lower matric potential (pressure by which water is held in the soil pores) in the sand, meaning the sandier soils can germinate seeds with less moisture. However, early establishment in sand at 1300 t/ha is less than for sand at 650 t/ha. This is due to deeper sowing in the high sand rate (despite best efforts to adjust seeder setup) reducing early emergence. The remaining treatments were no different to the control at this timing.

Following 40 mm of rain during June, crop establishment was improved by all sand and straw rates when assessed in early July (Table 4). In general, the establishment was similar across the three rates of straw trialed, averaging 88%. However, for the sand, application rates >650 t/ha resulted in the highest crop establishment (>91% of the plot emerged).

In general, NDVI assessments in late winter-early spring show that crop biomass was improved by the two higher application rates of both sand and straw. Similar to crop establishment the lower rates of both products also increased NDVI compared to the control. These results show three years after application, the straw and sand rates are having a positive impact on crop establishment and biomass on a saline soil.

*Table 4. Crop establishment and GreenSeeker NDVI for the salinity management trial Tickera, SA 2024.*

| **Treatment** | **Establishment %** | | **NDVI** | |
|---|---|---|---|---|
| | **May 31** | **July 9** | **July 12** | **Sept 11** |
| Control | $0.3^{d}$ | $50^{e}$ | $0.191^{d}$ | $0.244^{d}$ |
| Sand @ 130 t/ha | $2.8^{cd}$ | $70^{cd}$ | $0.222^{cd}$ | $0.502^{bc}$ |
| Sand @ 650 t/ha | $55.0^{a}$ | $91^{ab}$ | $0.383^{a}$ | $0.653^{a}$ |
| Sand @ 1300 t/ha | $16.3^{bc}$ | $98^{a}$ | $0.276^{bc}$ | $0.702^{a}$ |
| Straw @ 3.3 t/ha | $3.1^{cd}$ | $81^{bc}$ | $0.230^{cd}$ | $0.434^{c}$ |
| Straw @ 6.6 t/ha | $6.3^{cd}$ | $86^{ab}$ | $0.268^{c}$ | $0.603^{ab}$ |
| Straw @ 10 t/ha | $21.9^{b}$ | $96^{ab}$ | $0.327^{ab}$ | $0.622^{a}$ |
| Gypsum @ 10 t/ha | $0.1^{d}$ | $63^{de}$ | $0.197^{d}$ | $0.279^{d}$ |
| | | | | |
| **P-value** | **<0.001** | **<0.001** | **<0.001** | **<0.001** |
| **LSD (≤0.05)** | **14.6** | **16** | **0.058** | **0.115** |

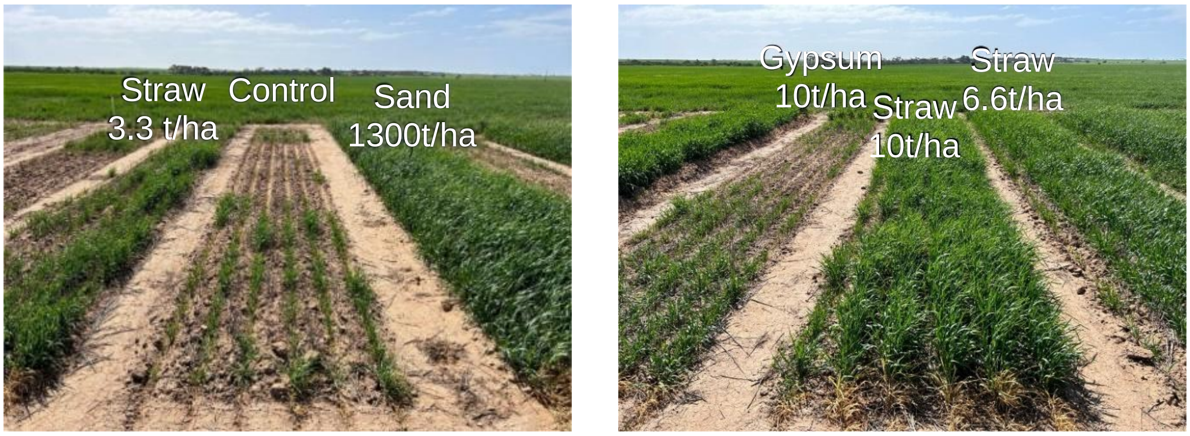


*Figure 1. Commodus CL barley in the control and various sand and straw rates (labelled above) in the salinity management trial Tickera, SA August 30, 2024.*

*Grain yield and quality*

Consistent with 2023, the two higher rates of sand (650 t/ha and 1300 t/ha) and straw (6.6 t/ha and 10 t/ha) improved barley grain yields compared to the control (Table 5). On average there was a 2.6 t/ha yield increase for these rates. The lower sand (130 t/ha) and straw (3.3 t/ha) rates also increased grain yield compared to the control, averaging a 1.1 t/ha yield improvement. These results show the sand and straw are providing significant benefits. Most likely through a mulching effect, reducing evaporation from the soil surface, retaining more moisture and reducing surface salinity. The higher rates of sand are also providing a layer of soil with lighter texture for crops to establish.

Similar to this season's grain yield results, cumulative yields are also showing all rates of sand and straw have improved grain yield (Figure 2). For the sand rates, grain yield stabilises after approximately 650 t/ha. That is, application of sand rates beyond this point did not result in larger yield gains. For the straw rates there is a linear response in cumulative grain yield (Figure 2). This suggests the straw rates trialed have not maximised grain yield and further gains may be achieved from rates above 10 t/ha.

Gypsum applied at 10 t/ha has not improved grain yield or quality compared to the control in any season to date. The soil test results this season showed the gypsum has moved into the 0-10 cm layer and reduced sodicity. However, the primary constraint of salinity has not been improved, as such, crop performance continues to be limited by salinity despite a reduction in sodicity. Long-term monitoring of this site will be required to understand the full soil, crop and economic returns from these treatments.

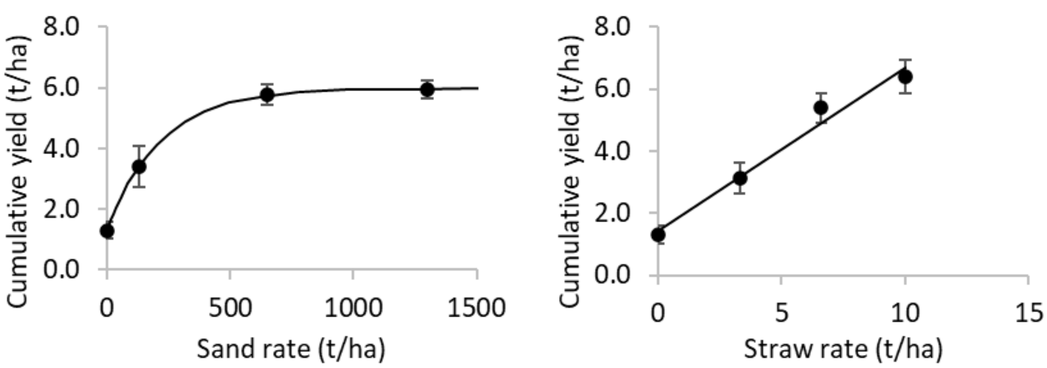


*Figure 2. Cumulative (2022 lentil + 2023 wheat + 2024 barley) grain yield response in relation to sand (left, $R^2$ = 0.867) and straw (right, $R^2$ = 0.978) rates applied in salinity management trial Tickera, SA.*

Grain quality from all the sand and straw treatments was higher (BAR1) compared to the control (BAR2) (Table 5). While Commodus CL has been approved for malt accreditation, all treatments within the trial had protein levels >12% (maximum level allowed). This reflects the below average growing season rainfall reducing grain fill in the trial which had lower yield potential (lower yield = higher protein).

*Table 5. Barley grain quality, receival standard and gross income for salinity management trial 2024 Tickera, SA.*

| Treatment | Protein % | Test weight kg/hL | Retention % | Screenings % | Receival standard |
|---|---|---|---|---|---|
| Control | 14.1[ab] | 61.5[e] | 71.3[b] | 8.9[a] | BAR2 |
| Straw at 3.3 t/ha | 13.5[abc] | 64.5[cde] | 82.2[a] | 4.9[b] | BAR1 |
| Straw at 6.6 t/ha | 12.5[c] | 67.1[a-d] | 86.1[a] | 2.6[b] | BAR1 |
| Straw at 10 t/ha | 13.1[bc] | 68.5[ab] | 84.6[a] | 3.0[b] | BAR1 |
| Sand at 130 t/ha | 14.2[a] | 64.9[b-e] | 80.4[a] | 5.0[b] | BAR1 |
| Sand at 650 t/ha | 14.1[ab] | 68.4[abc] | 87.9[a] | 2.6[b] | BAR1 |
| Sand at 1300 t/ha | 14.5[a] | 68.9[a] | 85.9[a] | 3.1[b] | BAR1 |
| Gypsum at 10 t/ha | 13.9[ab] | 62.5[de] | 69.0[b] | 10.2[a] | BAR2 |
| | | | | | |
| **P-value** | **0.023** | **0.011** | **0.001** | **0.001** | |

*Partial gross margin analysis*

Partial gross margin (PGM) analysis conducted on the three seasons of trial data shows positive returns for most treatments (Table 6). The highest PGM come from straw applications where the straw is sourced and spread cheaply. In this scenario cost recovery was achieved after two seasons for straw applied at 6.6 t/ha and was generating profit in the third season (Figure 3). However, sourcing straw at commercial value ($90 /t) and paying full contract rates for spreading reduced PGM below the control (<$500 /ha) after three seasons (Table 6). While spreading straw cheaply can be achieved on smaller areas of paddocks, it may not be practical over a larger area.

Despite the high costs of spreading sand as an amelioration strategy, it has produced positive PGM outcomes for the lower rates in the short term. The 130 t/ha and 650 t/ha have resulted in cumulative PGM of $838 /ha and $668 /ha, respectively (Table 6). Sand applied at 650 t/ha did not achieve cost recovery until the third season, whereas 130 t/ha had recovered costs in year 2 and was more profitable in year 3 (Figure 3). However, the trends of these lines would indicate that the higher cost 650 t/ha treatment will surpass the lower cost treatment in the near term. Currently the results show the 1300 t/ha sand application rate is too costly to apply and has a negative PGM. However, the longevity of all treatments will continue to be assessed and may impact the final economics on which product and rates will be optimal for the longer-term management of saline soils in the area.

*Table 6. Treatment costs, grain yields (t/ha) and partial gross margin for 2022-2024 in the sand, straw and gypsum treatments at Tickera, SA.*

| Treatment | Treatment cost* ($/ha) | 2022 Lentil | 2023 Wheat | 2024 Barley | Cumulative | Cumulative partial gross margin** |
|---|---|---|---|---|---|---|
| | | Grain yield (t/ha) | | | | ($/ha) |
| Control | $0 | 0.23$^{b}$ | 0.67$^{c}$ | 0.58$^{c}$ | 1.30$^{c}$ | $526 |
| Sand at 130 t/ha | $240 | 0.25$^{ab}$ | 1.26$^{bc}$ | 1.76$^{b}$ | 3.41$^{b}$ | $838 |
| Sand at 650 t/ha | $1,185 | 0.40$^{ab}$ | 1.97$^{ab}$ | 3.32$^{a}$ | 5.77$^{a}$ | $668 |
| Sand at 1300 t/ha | $2,370 | 0.62$^{a}$ | 2.26$^{a}$ | 3.16$^{a}$ | 5.95$^{a}$ | -$315 |
| Straw at 3.3 t/ha | $270-$625 | 0.40$^{ab}$ | 1.19$^{c}$ | 1.63$^{b}$ | 3.12$^{b}$ | $854-$499 |
| Straw at 6.6 t/ha | $545-$1,310 | 0.46$^{ab}$ | 1.95$^{ab}$ | 2.89$^{a}$ | 5.39$^{a}$ | $1,222-$457 |
| Straw at 10 t/ha | $825-$1,920 | 0.46$^{ab}$ | 2.42$^{a}$ | 3.50$^{a}$ | 6.38$^{a}$ | $1,265-$170 |
| Gypsum at 10 t/ha | $465 | 0.16$^{b}$ | 1.26$^{c}$ | 0.65$^{c}$ | 1.53$^{c}$ | $219 |
| | | | | | | |
| **P-value** | | **0.001** | **<0.001** | **<0.001** | **<0.001** | |

**Treatment costs have been estimated based on contract rates for sand spreading in the area (where sand can be sourced is within 1 km of the paddock applied) and a combination of contract rates and estimates of 'do it yourself' straw spreading options. Gypsum prices are based on Everard gypsum delivered and spread at Tickera.*

***Cumulative partial gross margin assumes grain prices of $700 for lentil, $300-$320 for wheat and $260-$284 for barley depending on receival grade achieved.*

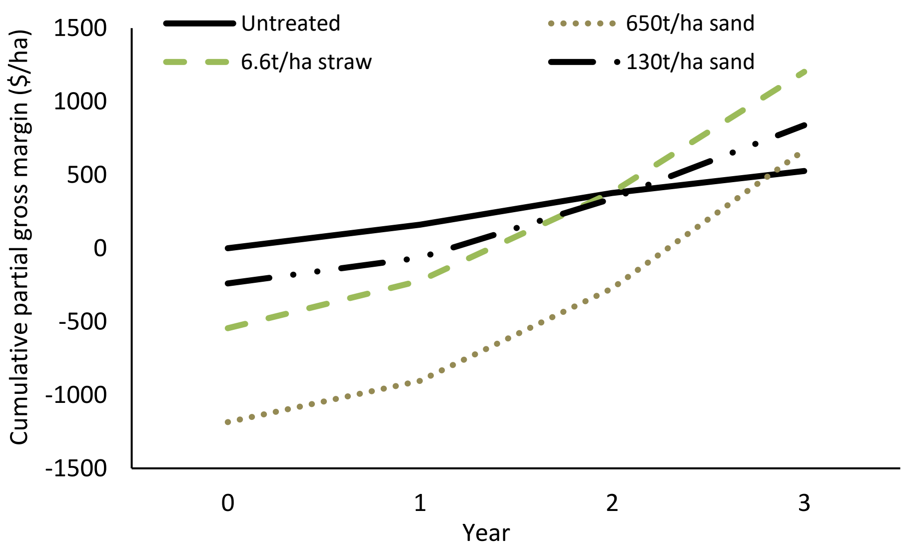


*Figure 3. Cumulative partial gross margin ($/ha) over time from initial treatment application for selected treatments. Lower cost ($545 /ha) estimate of 'do it yourself' scenario used for straw applied at 6.6 t/ha.*

## Summary

All straw and sand rates are having a positive impact on grain yield three years after application to ameliorate this saline soil. However, the highest grain yields were achieved when at least 650 t/ha of sand or 6.6 t/ha of straw were applied. The application of sand at that rate is logistically difficult unless a source is located nearby. Where sand is not locally available, application of straw at a minimum of 6.6 t/ha would be more achievable.

Partial gross margin analysis has shown most treatments have produced a positive return compared to the control. It is expected that grain yields will continue to be maintained or improved in the short term now that consistent crop cover has been achieved and salinity levels have declined in response to treatment. It is likely this will continue to increase the PGM for all sand and straw treatments going forward. The longevity of response is important for these amelioration treatments due to the high implementation cost and this trial will be monitored for another three seasons (six total).

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Australian Government Department of Agriculture, Fisheries and Forestry | Future Drought Fund | SA DISCOVERY FARMS

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