Lower Eyre Agricultural Development Association

LEADA

Soil Modification on Lower Eyre Peninsula Improving Access to Soil Moisture

Government of South Australia
Eyre Peninsula Natural Resources Management Board

LEADA

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Summary of Results and Key Messages (refer Case studies for more detailed analysis)

- The soils most at risk of a changing climate also offer the greatest opportunity to increase agricultural production through better use of the available soil moisture and this can be increased through soil specific modifications
- Current crop water use efficiency is the greatest indicator of the likely response to implementation of soil modification treatments – crops with low water use efficiency are more likely to provide the greatest response
- The greatest benefits to production have resulted where amelioration of the major constraint in the subsoil has been achieved
- The deep incorporation of organic matter accelerates changes to soil properties following claying of sandy soils
- Shallow mixing of ameliorants delivers some benefits only where constraints are also shallow
- Clay application increased soil pH and exchangeable cation exchange capacity
- Spading delivers mixed results depending on the nature of the soil and the amount of mixing of soil horizons involved in the spading process. Changes to soil chemical properties may not persist and the major constraints and the depth of influence needs to be understood prior to implementing spading programs. However, spading is a cheap option to mix soil horizons addressing low soil carbon in bleached A2 layers and potentially water repellence in the short term.

Introduction

There are an estimated 160,000ha of soils on Lower Eyre Peninsula that have known soil constraints that negatively impact on agricultural production that can be addressed through current soil modification techniques. These include soils with poorly structured subsoils and sandy soils with low water holding capacity and poor fertility.

In the past 2 or 3 decades research organisations and farmers have conducted trials and have applied various soil modification techniques in an attempt to address these constraints. There has been limited review of the success or otherwise of these operations in the long term. As a result there is little understanding of the benefit of treatments or of their longevity. Responding to increasing levels of interest in soil modification by group members the Lower Eyre Peninsula Agricultural Development Association (LEADA) developed a project to undertake a review of soil modification in the district. The outcome was to develop some guidelines to support farmers in making decisions on which soils can be modified, the best treatments and likely benefits. Funding was obtained from the Eyre Peninsula Natural Resource Management Board to assist in this work.

Method

Discussions within the LEADA Committee determined that a minimum of four previously modified sites would be revisited with production data collected and soil analysis to identify changes to soil physical and chemical characteristics. Feedback was invited from members on potential sites that could be revisited and the sites were selected based on:

- Ability to confidently locate the site and distinguish individual treatments
- Time since modification
- Soil type and historic evidence of differences resulting from treatments

Unfortunately due to limitations on the availability of baseline data and certainty of locating treatments only sites on sandy soils were selected (Table 1)

Table 1: Sites resampled

Land holder/site ID	Location	Soil type	Year Established	Treatments
Young Site 1 (BuAg)	Ungarra	Sand over clay (delved 2009)	2010	Delved, Delved + spading, Delved + organic matter + spading
Young Site 2 (LEADA)		Shallow sand over clay	2009	Spading, Spading + organic matter, Unmodified control
Housten	Ungarra	Shallow sand over clay	2009/2010	Spading spring 2009, Spading Autumn 2010, Unmodified control
Modra (heavy)	Karkoo	Sand over clay	2010	Clay, Clay + spading, Clay + organic matter + spading, Unmodified control
Treloar	Edillilie	Shallow sand over clay	2009	Spading, Spading + organic matter, Unmodified control

Biomass data was collected on sites in August/ September 2015 and yield data was collected in December, except for the Modra site that was in crop with canola that made data collection difficult. Soil sampling was undertaken in February 2016 and samples were sent for laboratory analysis. All samples were analysed for soil organic carbon (SOC Walkley Black) and based on carbon results a subsample of treatments were sent for more detailed nutrient and chemical analysis. Results were then subject to statistical analysis.

Site summation:

Terry Young BuAg: There appears to be on-going production benefits from spading a previously delved site, the addition of organic matter grown on the site has enhanced these benefits delivering over a 1t/ha yield increase. There also appears to be improvements to soil properties including increases in soil organic carbon stocks. This benefit is supported by analysis conducted on another trial site in a nearby paddock.

Peter Treloar, Edillilie: There appears to be on-going increases to plant production on this site but variability in data (potentially resulting from a combination of differences in depth to clay, treatment application and seeding patterns) have made interpretation difficult. Soil data is also questionable and requires further analysis.

John Housten, Ungarra: Consistent with the findings of the initial year of the trial there were no differences in plant production on this site in 2015. However, yields on this site were close to district average of the “better” soil types so this site does not appear to have the soil constraints found in many soils on Lower Eyre Peninsula.

Leon Modra, Karkoo: Plant performance data was not collected at this site as the paddock was under canola. Soil analysis has given some mixed results that are being further investigated.

There were several issues that may have impacted on the results obtained in this review. They include:

- Certainty of sampling within a treatment – on the sites with smaller plots GPS data was not very reliable. This issue was overcome in these cases by undertaking some preliminary soil sampling to identify areas of disturbance or clay mixing. However, where treatments involved both mixing of clay and organic matter there is greater uncertainty in results.
- Obtaining reliable plant production data was difficult in some cases due to crop type (canola) and changes to sowing patterns.
- There are some unexpected results in the soil data. This could result from inherent site variability or management factors such as movement of soil from adjacent plots, preferential grazing or higher nutrient removal on modified soils resulting in deterioration of nutrient levels.
- Seasonal conditions – a dry spring may have impacted differently on different treatments. Also an excellent start to the season would have limited the impacts of water repellence and promoted good early crop vigour. Ideally results would be collected over several seasons.
- Generally the differences in plant production and soil organic carbon were less obvious on sites with shallow B horizons (clay). Prior to modification these sites generally have better water use efficiency than deeper sands. Also with stubble retention and no-till technologies practiced for a number of years on these soils soil organic carbon levels in the top 10-15 cms of these soils may have been already increasing.

The final conclusion is that where soils have low water use efficiency soil modification can deliver long standing, if not permanent, improvements to soil characteristics with improved production outcomes. However, the modifications investigated in this study are not suitable for all soil types and even where appropriate may not deliver the maximum potential benefit. This may be due to implementation method or post management techniques.

Case Study 1. Terry Young, Ungarra

Enterprise: Mixed grain and sheep production.

Rainfall: 450 mm

Site 1 (BuAg)

Location: Youngs Road, Ungarra

Site Description:
This site is flat to gently undulating sand over clay soil with clay at 35 cms deep. The soil profile consists of:

0-10 cms: grey siliceous sand

10-35cms: bleached siliceous sand

35 cms +: Yellow brown, sodic, medium clay becoming increasingly calcareous with depth.

Figure 1. Ungarra BuAg site

The site was delved in 2009 and in spring 2010 a trial site was developed. The site involved 3 base treatments of 20 x 100 m plots. Treatments comprised:

1. Delved only
2. Delved + spading
3. Delved + spading + green manure (lupin crop)

Grain yield in 2015 (figure 2) was higher on the spaded only treatment with higher levels again on the spaded with organic matter treatment. The high biomass grown and the low conversion of biomass to grain yield compared to other sites suggests that there are still issues not resolved on this site. This suggests some further investigation is required.

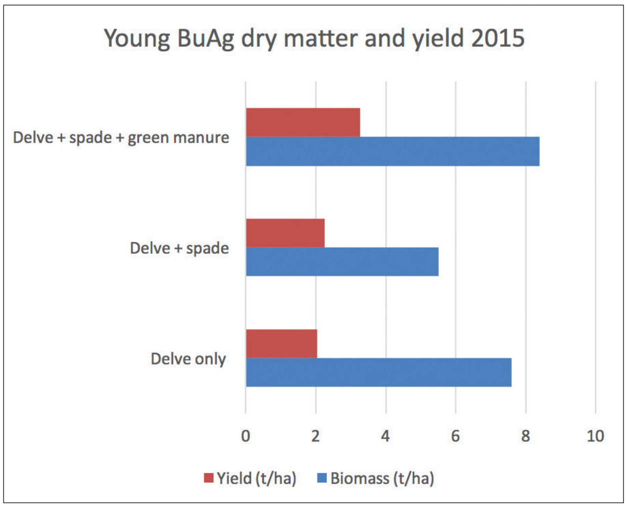

Figure 2. Dry matter and yield 2015

Soil samples were taken in January 2016 and analysed for soil organic carbon (SOC). Using bulk density data the carbon percentage was converted into carbon stocks (tonnes/ha). Results show that the spaded treatment had higher levels of SOC than the control and that the spaded with organic matter treatment had even higher carbon levels. Consistent with previous studies the largest differences occurred in the 10-20 cms and 20-30 cms depths. (Figure 3).

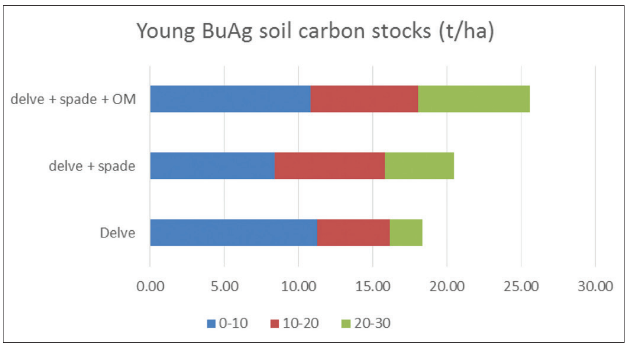

Figure 3. BuAg Soil organic carbon stocks

Conclusion

These results indicate that previously delved sites may deliver greater benefits to production through better mixing of clay and soil horizons through the spading operation. There also appears to be increases in soil organic carbon (SOC). Spading could be expected to improve the distribution of clay and also break up large clay clods to smaller clod sizes. This could provide greater protection to organic matter from biological attack. Also the higher plant production with greater plant root mass may deliver higher carbon levels. However, due to the relatively short time frame since application of the organic matter it is possible that the higher levels of SOC in the organic matter treatment may also be due to residual carbon applied in the treatment. To try to develop further understanding of soil carbon relationships following modification a further trial site on the same property was investigated

Terry Young (LEADA site)

Location: Moody Centre Road, Ungarra

This site is similar to the BuAg site being flat to gently undulating sand over clay soil with clay slightly shallower (25-50cms) (Figure 1).

The profile consists of a shallow sand to 20/25cms over a sodic clay (figure 4)

Figure 4. Young "LEADA" trial site

Table 1. T. Young LEADA Trial Plan

2.5m

Spaded + N, P,TE	Spaded + Bactivate	Spaded	Spaded + N, P
Control + N, P,TE	Control + Bactivate	Control	Control + N, P
Spaded hay +NP,TE	Spaded + hay + Bactivate	Spaded + hay	Spaded + hay + N, P
Spaded + N, P, TE	Spaded + Bactivate	Spaded	Spaded+ N, P
Spaded + hay + N, P, TE	Spaded hay + Bactivate	Spaded + hay	Spaded + hay + N, P
Control + N, P, TE	Control + Bactivate	Control	Control + N, P

8m

10m

The original trial comprised 3 main treatments (control, spaded and spaded with organic matter) replicated twice with nutritional treatments traversing the main treatments (Table 1).

Due to difficulties in precisely locating the old plots no biomass or grain yield was collected. However, changes to soil organic carbon were measured through taking a series of sample points on a transect across the trial site. Soil samples were collected at four depths, 0-10, 10-20, 20-30 and 30-50 cms and clay weight and organic matter percentage was determined. Comparison of clay levels in relation to soil organic carbon was conducted with no trend apparent (Figure 5).

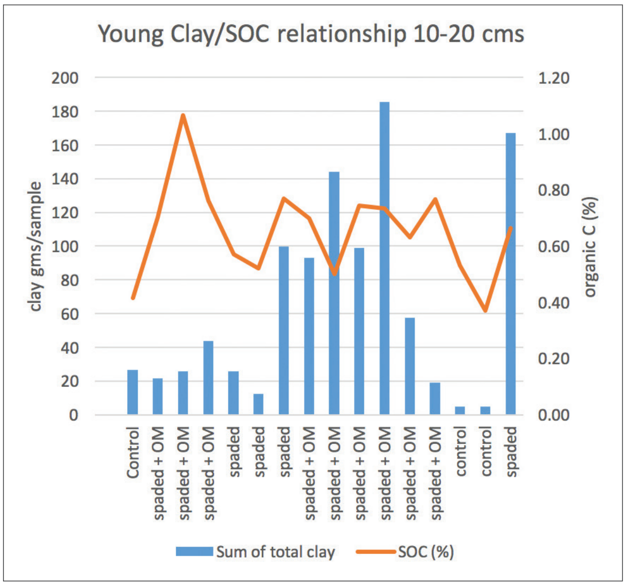

Figure 5. "LEADA" clay and organic carbon 10-20cms

However, it is also apparent that the combination of clay + organic matter has increased soil organic carbon at this depth and carbon stocks to 0-30cms throughout the trial (figure 6).

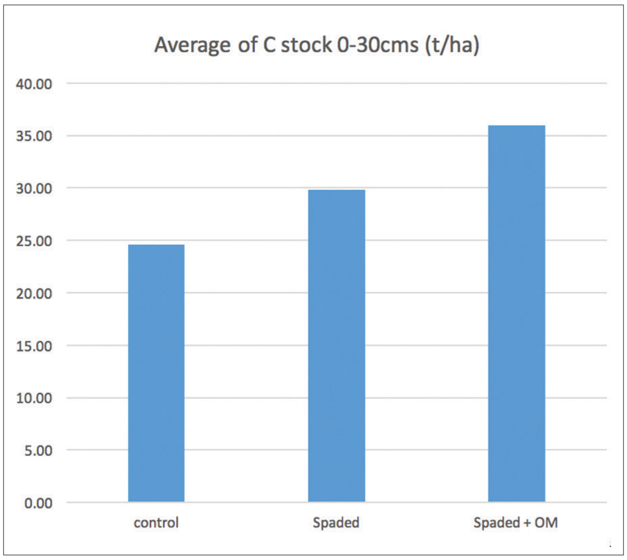

Figure 6. "LEADA" carbon stocks 0-30 cms

This data confirms previous data obtained from the site suggesting that changes to soil characteristics are persisting and that increases in carbon are not just residual carbon from previous applied organic matter.

Case Study 2. Peter Treloar

Location: Koppio Rd, Edillilie

Enterprise: Mixed grain and sheep production.

Rainfall: 480 mm

Site description:
This site is flat to gently undulating (figure 1) with a soil profile consisting of a shallow sand to 20/25cms over a sodic clay (figure 2).

Figure 1. Treloar trial site at Edillilie

Figure 2. Treloar site soil profile

The original trial comprised 3 main treatments (control, spaded and spaded with organic matter) replicated twice with nutritional treatments crossing the main treatments. The trial was monitored for three years with the spaded with organic matter treatments delivering higher yields than the control (figure 3).

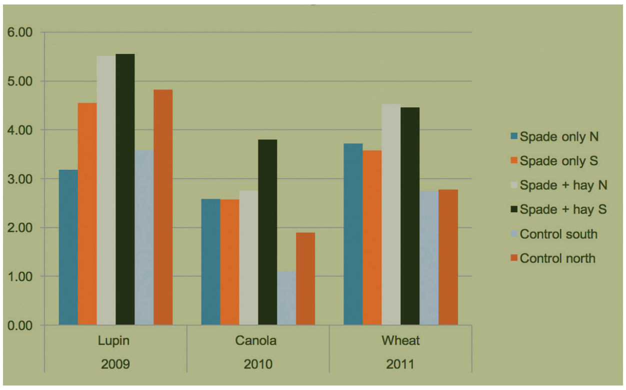

Figure 3. Crop yields 2009-2011

The site was revisited in 2015 and plant biomass (dry matter) cuts were taken in September 2015. Due to a change in sowing pattern, the trial is now located on a headland making it difficult to obtain a representative sample. This factor combined with inherent site variability and/or variability in treatment may have delivered different results within treatments. However, the spaded and spaded + organic matter treatments delivered higher biomass and, apart from spaded north plot, yielded higher than the control (Figure 4).

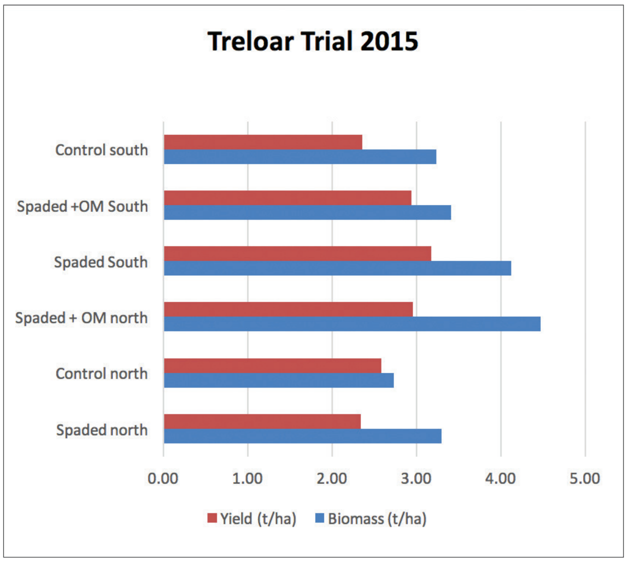

Figure 4. Plant production data 2015

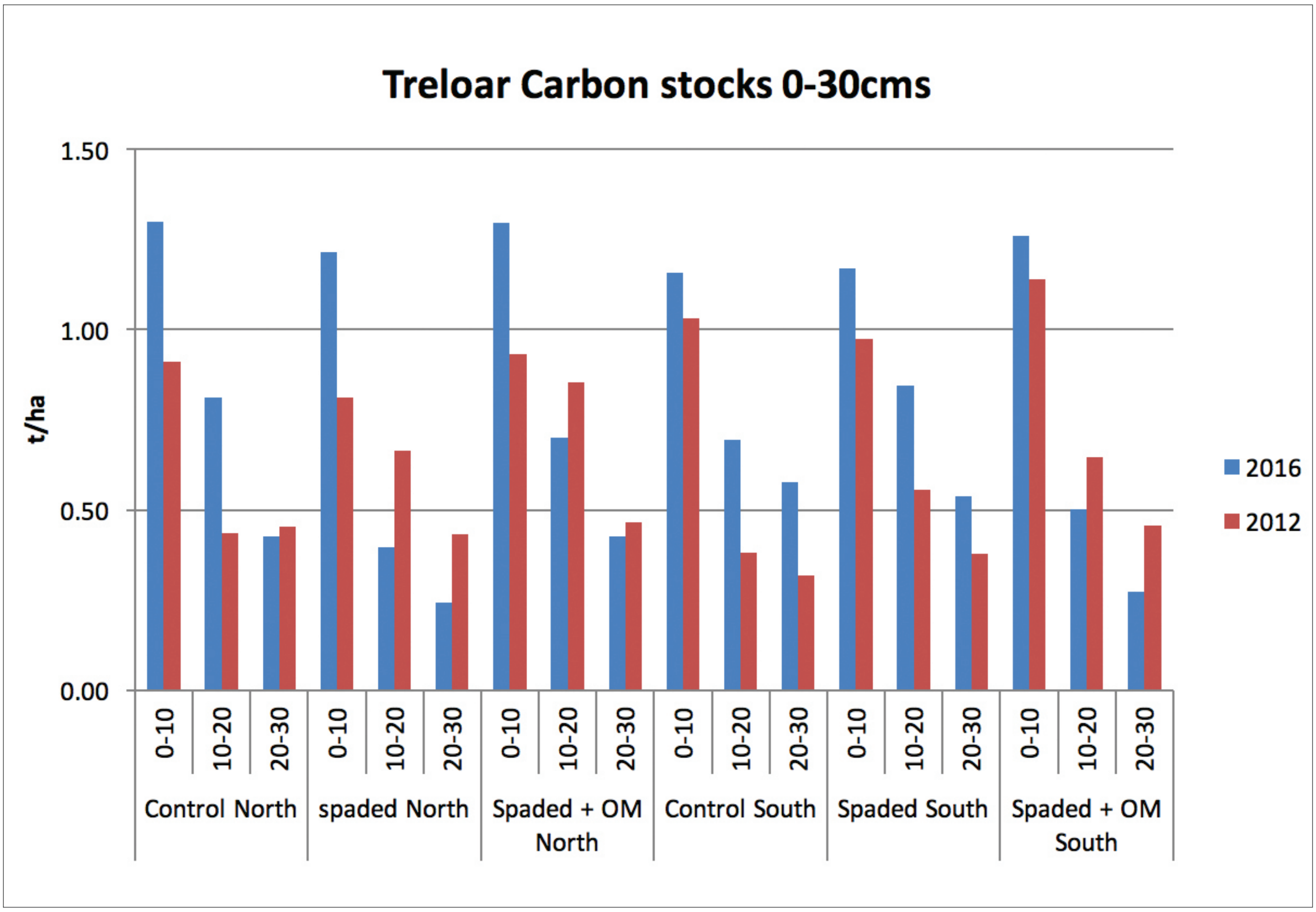

Figure 5. Soil Carbon Stocks 2012 and 2016

Variability in the data could reflect differences in soil characteristics across the site and/or issues with sampling method. The particularly dry spring may also have impacted on conversion from biomass to yield with some of the highest biomass treatments having a poor conversion rate. Despite this, the average yield of the spaded + OM treatments of 2.95 t/ha is favorable compared to the average of the control plots at 2.46t/ha. However, this is still below the district average yield suggesting that there is room to further improve treatments to this site.

Soil samples were taken in late January 2016 and forwarded for laboratory soil analysis. Spaded treatments showed higher soil pH and cation exchange capacity (CEC). Soil organic carbon levels (SOC) did not reflect expected trends with the control plots having higher carbon stocks than the other treatments (figure 5).

These findings do not accord with carbon stock data obtained in 2012 and this data is being treated with caution and further analysis is being undertaken to try to clarify the results.

Conclusion

During the three years following establishment this site showed increases in plant production from the applied treatments. These trends appear to be maintained but relation of yield to treatment in 2015 is not as clear. This may be due to seasonal conditions or reflect reduction in benefit over time. Despite this uncertainty the early benefits delivered and indications of ongoing higher yields would suggest modification treatments at this site should be adopted on similar sites in this district.

Case Study 3. John Housten

Enterprise: Mixed grain and sheep production.

Rainfall: 420 mm

Location: Road, Butler?

Site Description:
This site is flat to gently undulating loamy sand/sandy loam over clay soil with clay at 35-50cms deep. The profile consists of a loamy sand/sandy loam over a light to medium clay with carbonate increasing at depth.

To assess the timing of spading the site was spaded in Spring 2009 and Autumn 2010 (Figure 2). A range of nutritional treatments were applied at this time.

Figure 1. Spading at the Housten site, Autumn 2010

Analysis of root DNA conducted in 2010 (Table 1) identified that the spading operations increased root mass in the 10-30 cms depth with the spring spading delivering the largest increase compared to the control.

Treatment (depth cms)	Root DNA (pgDNA/g)
Control 0-10	644
Control 10-30	1001
Spaded Spring 0-10	508
Spaded spring 10-30	2904
Spaded Autumn 0-10	470
Spaded autumn 10-30	1819

Table 1. Root DNA levels 2010

The spaded treatments also delivered higher dry matter levels with the spring 2009 treatment (green manure) recording the highest levels (Figure 2). However, this was not converted to yield with no significant differences across treatments.

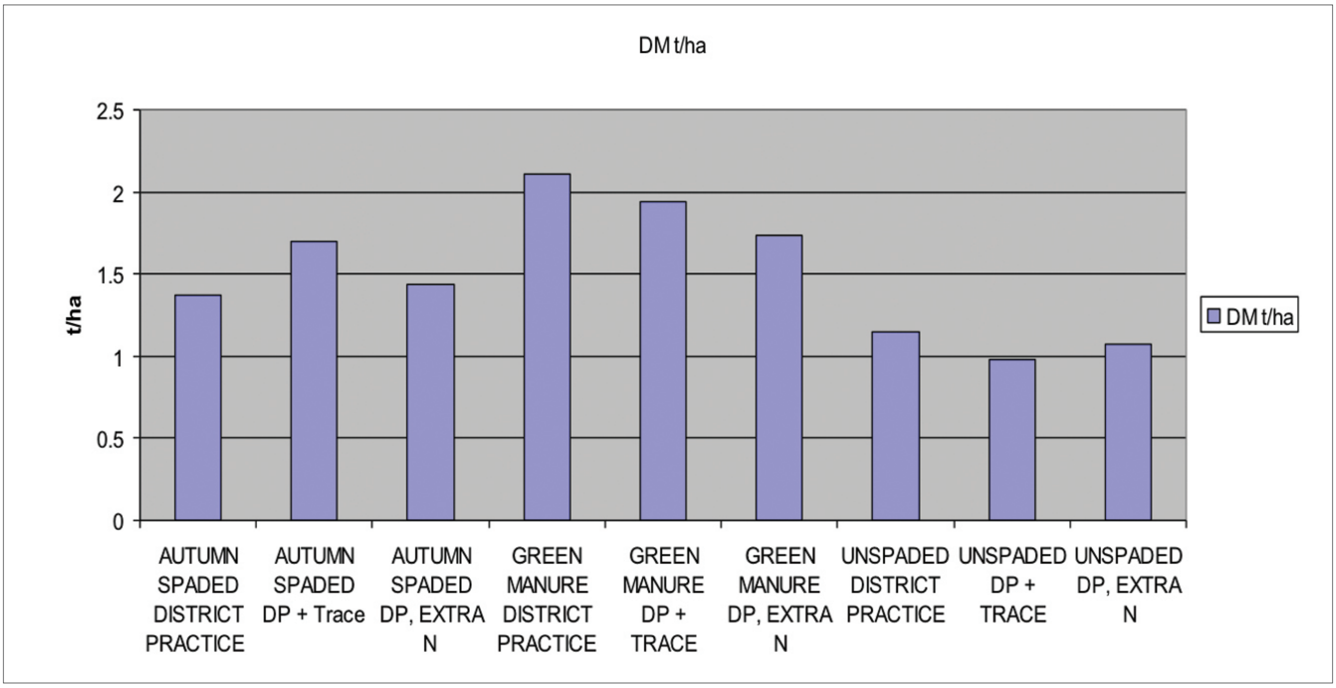

Figure 2. Housten site, Dry Matter2010

Monitoring conducted in 2015 showed little difference in plant biomass or yield (Figure 3). Yields across all treatments were over 4t/ha which are considered to be quite high for this district. This suggests that the soil characteristics of this site did not greatly constrain yield.

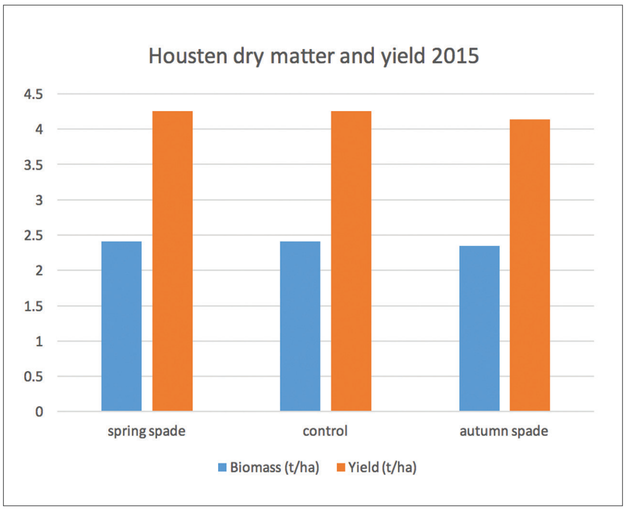

Figure 3. Housten dry matter and yield 2015

Soil analysis showed that the control and the spring spaded treatments had similar soil carbon stocks but that the autumn spaded treatment had higher levels (Figure 4). The reasons for this are unclear and further soil analysis is being undertaken to confirm if this is just a result of site and/or sampling variability.

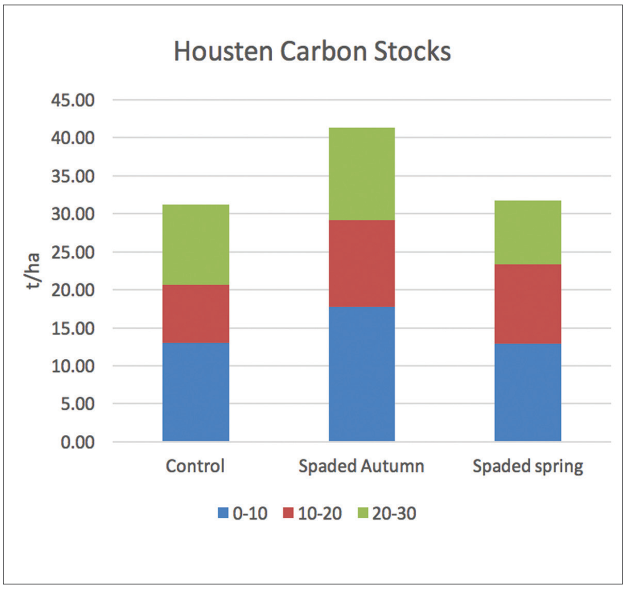

Figure 4. Housten soil carbon stocks 2016

Conclusion

Treatments on this site did not provide yield increases in either 2010 or 2015. The comparatively high yields delivered by this site suggests that soil constraints are not a major issue limiting yield in years with average rainfall, such as in 2015. The higher soil carbon levels of the autumn spading need to be validated. If confirmed the higher soil carbon levels could deliver benefits to soil properties such as soil structure that may deliver yield benefits in less favorable years. This potential will be explored further.

Case Study 4. Leon Modra

Location: Road, Karkoo

Enterprise: Mixed grain and sheep production.

Rainfall: 400 mm

Site description:

This site is a gently undulating deep sand over clay soil with clay between 40-50 cms deep. The clay is slightly calcareous with levels increasing with depth.

The site was originally clay spread in 1995 at around 250t/ha and in 2012 a trial was established. Treatments included:

- Untreated control
- Spaded only
- Organic matter (10 t/ha lupin grain) incorporated to 30 cm using a spader.
- Clay incorporated to 10cms
- Clay incorporated (spader) to 30 cm.
- Clay + Organic matter (10 t/ha lupin grain) incorporated to 30 cm using a spader.

Figure 1. Trial showing clay + spading treatment in foreground and clay + organic matter + spading with lupins germinating in the background

There were large differences in biomass and yield in 2012 with all treatments exceeding the control in dry matter and yield (Figure 2 and Table 1).

Figure 2. Trial showing greater growth of the clay + organic matter + spading treatment

Treatment	Dry matter (t/ha)	Grain Yield (t/ha)	Grain Yield % of control
Control	5.6	4.7	100
Spaded	8.3	6.6	140
Organic matter + spaded	9.8	5.5	117
Clay spread	5.5	5.1	108
Clay + spaded	7.9	5.4	114
Clay + organic matter + spaded	10.4	6.3	134

Table 1. Dry matter and yield 2012

As the trial paddock was in canola in 2015 no plant production data was collected. However, soil sampling was undertaken to identify if there were any changes to soil properties that could beneficial to production.

Soil samples were collected in February 2016 for soil organic carbon and nutrition analysis and in March 2016 for bulk density analysis.

Soil organic carbon levels did not reflect expected trends with the control plots recording relatively high SOC levels that were even higher than the clay treatments (figure 3). This does not accord with previous experience and the data must be treated with caution. Further analysis is being conducted to determine changes to other soil characteristics and to confirm validity of current data.

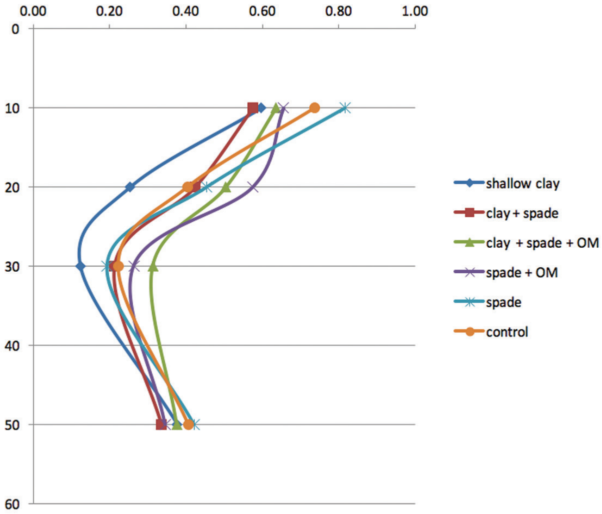

Figure 2. Trial showing greater growth of the clay + organic matter + spading treatment

Conclusion

The objective of this study was to determine ways to increase agricultural production and resilience in the face of a changing climate. The study focused on poorly performing soils on Lower Eyre Peninsula as it was considered that while these soils are most at risk of a changing climate and they also offer the greatest opportunity to increase agricultural production through better use of the available rainfall. This was done by examining previous trials conducting soil modification techniques to determine if any of these technologies delivered long term changes to production and soil characteristics.

Although a one year study can only provide a snapshot of production two of the three sites where production data was collected demonstrated that previously observed production benefits were still apparent some years after soil modification.

The site that did not show any production increases in 2015 from soil modification conducted previously was also the most inherently fertile of the sites delivering the largest yields. Soil data collected on five sites showed increases to soil pH and cation exchange capacity following soil modification on all sites. Soil organic carbon data however was highly variable with 3 of the five sites showing higher carbon levels on modified treatments but the other two sites delivered unexpected results with the unmodified controls delivering values similar to the modification treatments. This data is being considered more closely as the levels from the analyses in 2015 are much higher than those previously measured.

Despite these questions there are some clear findings from this work including:

- The addition of clay to sandy soils on Lower Eyre Peninsula does increase soil inherent fertility, pH and generally soil organic carbon levels. These factors do deliver substantial increases in production over the long term.
- The addition of clay appears to be a "one off" treatment with differences in clay levels on treated sites observed up to twenty years post application.
- The incorporation of organic matter enhances soil organic carbon for at least 3 years following application. Increases are greater than the amount of carbon applied in the treatment suggesting that carbon input from another source is occurring (probably carbon from increased root mass at depth).

Although there were no benefits to production observed from mixing of soil and organic matter into a heavier soil type that has no identified soil constraints there may be improvements to soil organic carbon. These need to be confirmed but if they have occurred the benefits to production may only be seen in challenging seasonal conditions. In any case the long term benefits to offsetting greenhouse gas emissions through increasing soil organic carbon are worth considering.

This study has been constrained through only conducting a review over one season. However, this is still important information that is adding to the overall knowledge and interest in soil modification. This has implications for both sustainable agricultural production and offsetting greenhouse gas emissions. There is no doubt that this work will be further developed into the future.

Acknowledgments

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