Section 7

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Soils

Addressing production constraints through the modification of sandy soils

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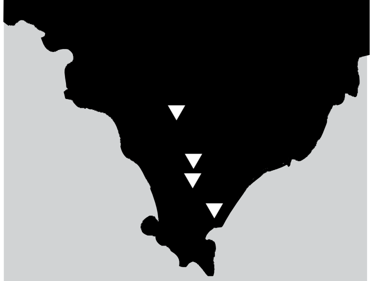
Searching for answers



Location:
Lock, Mt Hill, Wharminda, Ungarra and Pillanna
Farmers: Gus Glover, Chris Will, Ed Hunt, Terry Young & Mick Dahlitz

Soil Type
Variable depth of sand with bleached A2 Horizon over clay

Soil Test
Mid season basic nutrition
Microbial biomass
Crop root DNA

Plot Size
Unreplicated demonstration site with varying plot sizes.

Yield Limiting Factors
Six week dry period in September
Potential competition from summer forage sorghum and ryegrass on spaded treatment at Young's

Key messages

- **Modifying soil using a spader only can give large increases in dry matter without necessarily giving the same increase in yield.**
- **Using the spader to incorporate a delved site can be effective in increasing the benefit of the delving operation, particularly where organic matter is also incorporated.**

Why do the trial?

Past trials and demonstrations have shown that the placement of clay and nutrients into A2 horizons (either by delving or deep incorporation through spading) have resulted in greater production increases than those achieved by modifying the A1 horizon only (clay spreading). The addition of organic material in this process can deliver even more significant results (EPFS Summary 2010, p154) but results have been inconsistent. The demonstrations summarised below have been conducted to improve our understanding of what is driving these responses and how soil modification techniques can be improved on sandy profiles.

How was it done?

A number of large plot demonstration sites were established using the spader prior to sowing in 2011 and monitored during the season. Yield data was also gathered on some existing sites (Table 1).

Sites were sown with farmer equipment and treated the same as the rest of the paddock during the season. Grain yield data was obtained from 6 x 1 metre row cuts at maturity and threshing out the grain. The Edillilie site was harvested using the SARDI plot header with three ten metre strips harvested from each treatment.

What happened?

Glover, Lock

The Glover site compared spading, spading with oaten hay (33 t/ha), spading with canola hay (30 t/ha) against a control of no soil modifications. Spader treatments were applied in early May 2011 with the site being sown to Maritime barley in the first week of June. Strong winds in late June resulted in erosion on the spaded treatment.

Plant emergence counts taken in early July showed little difference between the control and the spaded only treatment. Plant density was 24% higher than the control on the spaded with oaten hay treatment and 200% of the control where canola straw was incorporated by the spader.

Dry matter in the spaded only treatment reflected the impact of erosion. Dry matter in the spader with canola straw treatment was much higher than any other treatment (Figure 1).

Table 1 Summary of demonstration sites

Co-operator	Location	Soil profile description	Plot size	Crop	Measurements	Treatments
Glover	Lock	Fine neutral grey siliceous sandy A1 to 10 cm over a bleached yellow siliceous sand (A2) to 50 cm with orange clay lamella from 30 cm. Orange clayey sand from 50 to 75 cm.	8 m x 20 m	Barley	Plant emergence, dry matter, mid season soil nutrients, root DNA, fungal biomass, yield	Non spaded, spaded only, spaded with oaten hay incorporated and spaded with canola hay incorporated, May 2011
Will	Mt Hill	Grey slightly acid sandy A1 to 10 cm over bleached A2 to 25 cm. Neutral orange/ brown clay B horizon beginning at 25 cm becoming increasingly calcareous and alkaline at depths greater than 35 cm.	4 m x 20 m	Wheat	Plant emergence, dry matter, mid season soil nutrients, root DNA, fungal biomass, yield	Non modified, spaded only, spaded with pelletised lucerne incorporated, delved only, delved and spaded, delved and spaded with pelletised lucerne incorporated, May 2011
Hunt	Wharminda	Shallow sand over clay. Profile not characterised.	12 m x 50 m	Wheat	Plant establishment	Non spaded, pasture green manured spring 2010, damaged by spray drift, no data collected
Young	Ungarra	Grey siliceous sandy A1 to 10 cm with bleached A2 to 25 cm. Yellow brown sodic medium clay B horizon becoming increasingly calcareous with depth.	20 m x 100 m	Wheat	Plant emergence, dry matter, mid season soil nutrients, root DNA, fungal biomass, yield	Delved in 2009, lupin crop green manured using spader in spring 2010, sorghum sown on spaded area, December 2010
Dahlitz	Pillanna	Shallow sand over clay. Profile not characterised.	8 m x 50 m	Wheat	Yield	Delved in December 2010, spaded in May 2011. Spaded with 20 t/ha pea straw incorporated
Treloar	Edillilie	Grey brown loosely structured loamy sand to 15 cm. Pale brown acidic sandy A2e horizon with 20-30% ironstone cobbles to 20 cm. Highly bleached white sandy A2 with 5% ironstone cobbles to 35 cm over a neutral orange/red brown medium clay B1 horizon beginning at 35 cm. Yellow brown sodic B2k horizon from 50 cm with carbonate increasing with depth.	12 m x 8 m	Wheat	Yield	Control, spaded and spaded with 10 t/ha of lucerne hay, March 2009

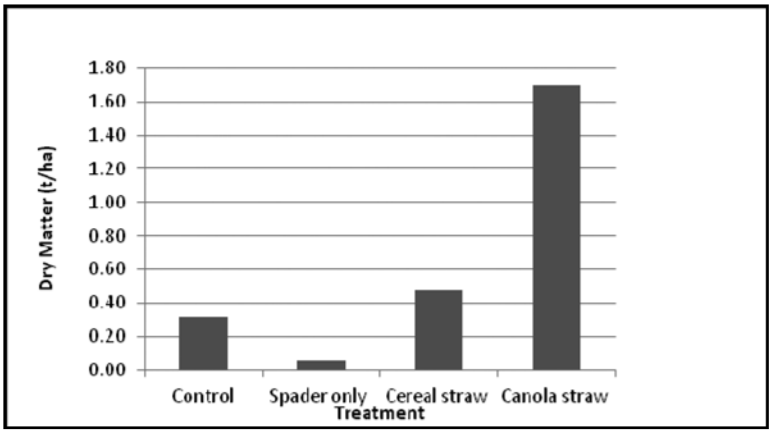


Figure 1 Dry matter from Glover site in August 2011

Soil samples were taken from each treatment at depths of 0-10 and 10-30 cm (the working depth of the spader) in early September and were analysed for basic nutrition, root DNA and fungal biomass. There was little difference in nutrient analysis results between the control, spaded only and incorporated canola hay treatments. Potassium, sulphur and nitrate levels were generally higher on the spaded plus cereal hay treatment.

Root DNA analysis indicated more wheat roots with spading and even more where organic matter was incorporated as well (Table 2). This was most obvious in the 10-30 cm depth.

Differences in dry matter production were also reflected in yield with incorporated hay treatments delivering three to six times greater yield than the control (Figure 2).

This demonstration confirms other work which suggests that incorporation of organic material will provide significant increases in yield. A number of questions were raised including:

- How long does the yield benefit from the incorporation of organic matter last?
- Why has the canola hay treatment provide such significant benefits? There are no obvious nutrition differences between canola hay, spaded only and the control, yet the canola treatment has delivered major dry matter and yield responses. Further investigation is required to determine the effect of different types of organic matter on crop growth response.
- What methods can be employed to reduce erosion risk following spading?

Table 2 Soil root DNA samples taken from Glover site in September 2011

Treatment	**Depth 0-10 cm** (pgDNA/g)	**Depth 10-30 cm** (pgDNA/g)
Control	18	0
Spaded only	67	318
Cereal Straw	118	1367
Canola Straw	4761	2743

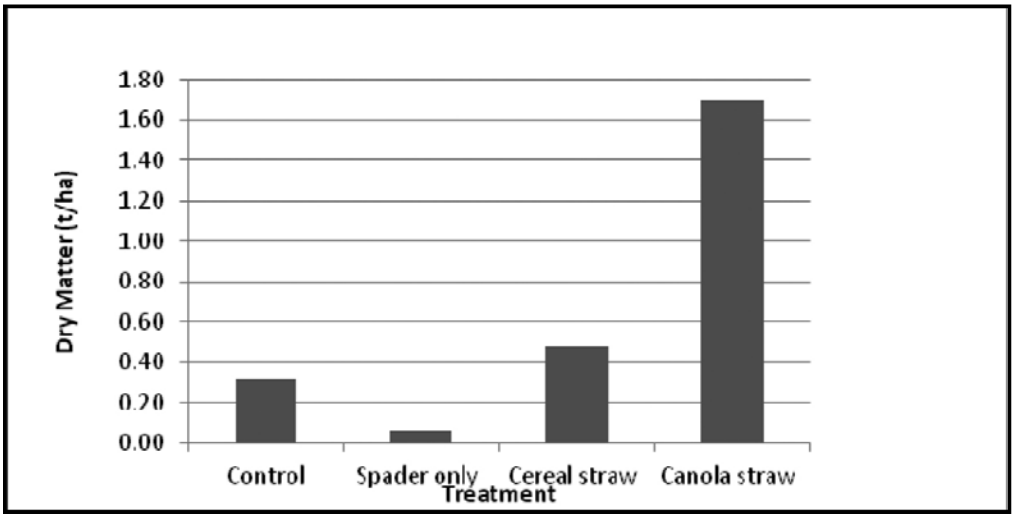


Figure 2 Glover barley yields, December 2011

Will, Mt Hill

A portion of the site was delved to a depth of 60 cm in April with spader and organic matter treatments (pelletised lucerne @ 10 t/ha) applied prior to seeding in May 2011.

Plant numbers in early July were slightly higher on spaded plots (5 to 19%) than the control, except for the delved + spaded treatment which had similar plant numbers to the control. There were 20% fewer plants on the delved only plot compared to the control. This may have been due to uneven germination resulting from poor incorporation of clay after delving.

Dry matter cuts in late July showed that all modified treatments except delved only recorded higher dry matter levels (13 to 32% higher) than the control (Figure 3). When comparing these dry matter weights against the variation in plant numbers there was a 10% increase in the kg/plant on the spaded treatments over the control and a 20% increase on the delved + spaded treatments indicating a growth response to the treatments. In September all soil modification treatments had higher dry matter production than the control.

Soil samples were taken from each treatment at depths of 0-10 and 10-30 cm in early September and were analysed for basic nutrition, root DNA and fungal biomass. Higher levels of sulphur, organic carbon and nitrogen were present in the 0-10 cm layer of the unmodified control and higher levels of potassium in the B horizon at 20-30 cm. The modified treatments had a more even distribution of nutrients throughout the profile than the control. All soil modification treatments had higher soil pH than the control. This is likely to be a result of bringing up alkaline B horizon material through the soil modification treatment. However change in pH was variable for each treatment which is likely to reflect the variability of depth to the B horizon and carbonate layer (pH increases ranged from 0.4 pH unit in the spaded + organic matter treatment to greater than 1 pH units for the delved + spaded treatments). The larger increases where the spader was used post delving could indicate the better ability of the spader to incorporate material brought up by the delver.

Wheat root DNA analysis showed:

- Fewer roots in the delve only treatments and in the 10-30 cm soil levels of the spaded only treatments.
- More roots in the 10-30 cm layer where organic material was incorporated than spading alone.

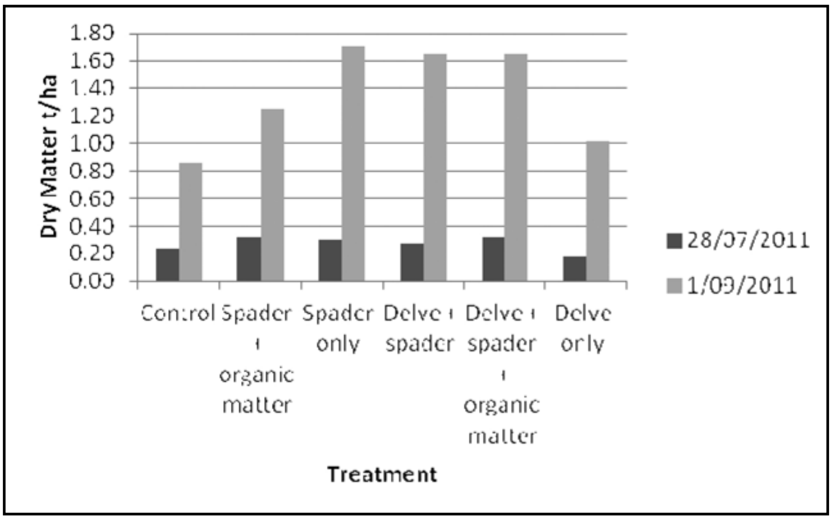


Figure 3 Dry matter from Will site in July and September 2011

Table 4 Wheat root DNA analysis from soil samples taken from Will site in September 2011

Treatment	**Depth 0-10 cm** (pgDNA/g) Sample	**Depth 10-30 cm** (pgDNA/g) Sample
Control	71352	62169
Spaded only	69531	22005
Spaded + OM	83577	34086
Delve only	17590	17634
Delve + Spade	79790	12726
Delve + Spade + OM	79943	71115

Microbial carbon analysis did not identify any particular trends resulting from the soil modification treatments. Further investigation is required to help quantify the impact of soil modification techniques on root development and microbial activity.

The large increases in dry matter production on the soil modification treatments in the middle of the season did not translate to similar increases in grain yields (Figure 4). The only treatments which gave yield increases greater than 10% were a combination of delving and spading.

These results do not accord with other demonstrations showing significant increases in production following incorporation of organic material. This requires further investigation and this site will be monitored in 2012.

Young, Ungarra

The objectives of this demonstration were to;

- Establish surface cover using a summer active pasture (forage sorghum) to reduce wind erosion risk following spading in spring (green manuring).
- Determine the impact of the summer crop on grain yield on the site in the following season.

Sorghum effectively eliminated wind erosion potential and produced approx 15 t/ha of dry matter over the course of the summer. However, it appeared to dry the soil profile (Table 5) with an impact on subsequent production (Figures 5 and 6).

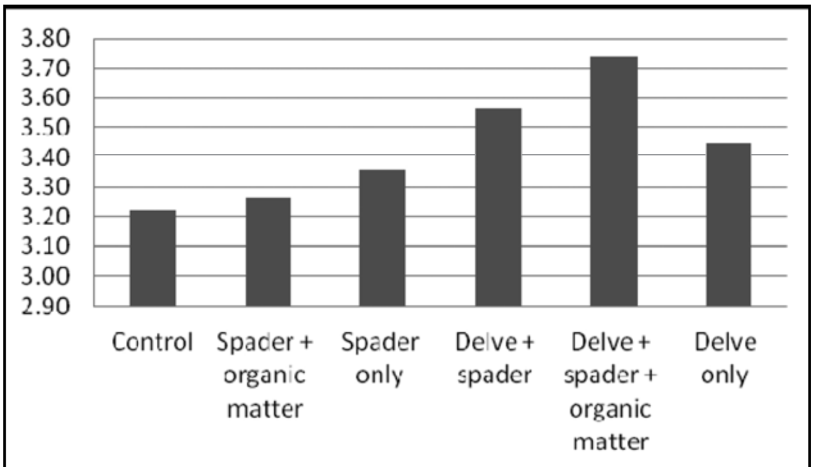


Figure 4 Will wheat yields, December 2011

Table 5 Gravimetric moisture content of Young site, May 2011

Depth	0-10 cm Gravimetric moisture (%)	10-20 cm Gravimetric moisture (%)	20-30 cm Gravimetric moisture (%)
Unspaded	10.33	9.83	14.50
Spaded	9.06	8.97	10.54

The spaded area suffered from a high infestation of ryegrass despite pre and post emergence treatments. Additionally crop emergence appeared be to more variable on the spaded area.

Dry matter in early September was 25% higher on the unspaded control than the spaded treatment. At this time the crop was also observed to be more yellow on the spaded area indicating nitrogen deficiency possibly due to depletion by the summer sorghum crop and ryegrass competition.

Soil samples were from each treatment at depths of 0-10 and 10-30 cm in early September and were analysed for basic nutrition, root DNA and fungal biomass.

The site was generally marginal in phosphorous and sulphur but did not identify any large differences between treatments or depths.

The pH of the unspaded control (pH 5.5 in $CaCl_2$) was 0.9 lower than the spaded areas at 0-10 cm and was 0.7 lower than the spaded areas at 10-30 cm depth (pH 5.7). This may indicate better mixing to 30 cm by the spader of the alkaline clay brought up by the delver.

Soil microbial levels were highest in the 0-10 cm depth in both treatments but were higher in the 10-30 cm layer of the spaded treatment than the control (Table 7). More investigation of plant root growth and microbial activities in modified soils is required to quantify the impact on crop yield.

Grain yields were 44% higher on the unspaded area than the spaded treatments (Figure 6), reflecting the differences in early dry matter production. This could result from the moisture and nutrient use by the summer sorghum crop or possibly from the increased ryegrass competition on the spaded area.

Table 7 Microbial carbon levels in soil samples taken from Young site in September 2011

Treatment	Microbial levels (ugC/g dry soil) Depth 0-10 cm	Microbial levels (ugC/g dry soil) Depth 10-30 cm
Control	141	29
Spaded only	132	67

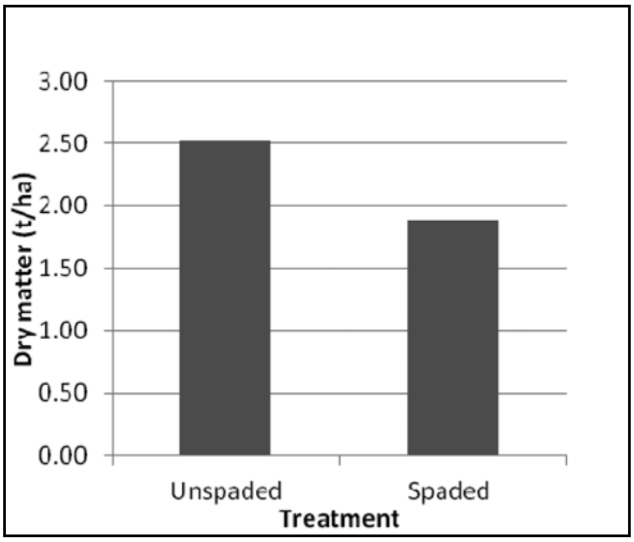


Figure 5 Dry matter at Young site September 2011

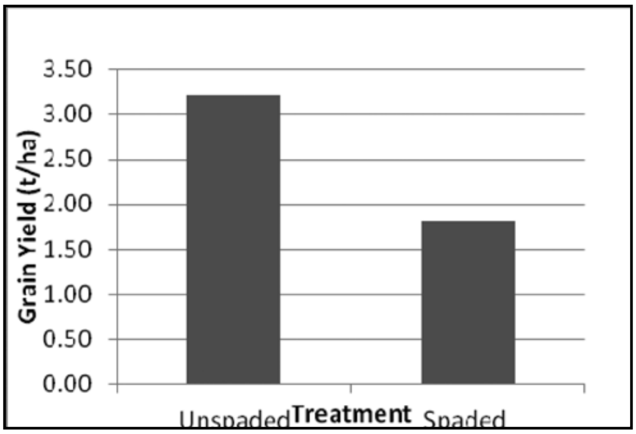


Figure 6 Young wheat yields, December 2011

Dahlitz site

Grain yield was 37% higher where pea straw was incorporated by the spader than on the spaded treatment alone (Figure 7).

Treloar site

This site was established using the spader in 2009. In 2009 the site was sown to lupins with a large yield responded on the spaded + lucerne straw treatment. In 2010 the canola yields were higher on the spaded treatment compared to the control and even higher where lucerne straw was incorporated.

In 2011 yield was 32% higher on the spaded only treatment and 62% higher where lucerne straw was incorporated than the control (Figure 8).

What does this mean?

This series of demonstrations has further illustrated the possibility of using soil modification techniques to increase crop yields on sandy soils. Results from these demonstrations have supported earlier work which suggests that while clay incorporation into sandy topsoils does provide yield benefits, further increases can be realised by incorporation of clay and organic matter. This poses further questions as to the impact of the addition of organic matter on crop growth, particularly root development and microbial activity.

The much greater dry matter and yield response from the incorporated canola straw compared with oaten hay at Glover's site poses further questions as to the best form of organic matter and its impact on soil microbial processes.

Other issues with regard to soil modification that require further investigation include:

- Does additional nitrogen need to be applied where cereal residues are incorporated to prevent the residue decomposition resulting in induced crop nitrogen deficiency?
- How long are the potential gains going to last?
- What are the implications for soil carbon levels? Identification of organic carbon fractions may assist.
- What is the impact of spading on weed management strategies?

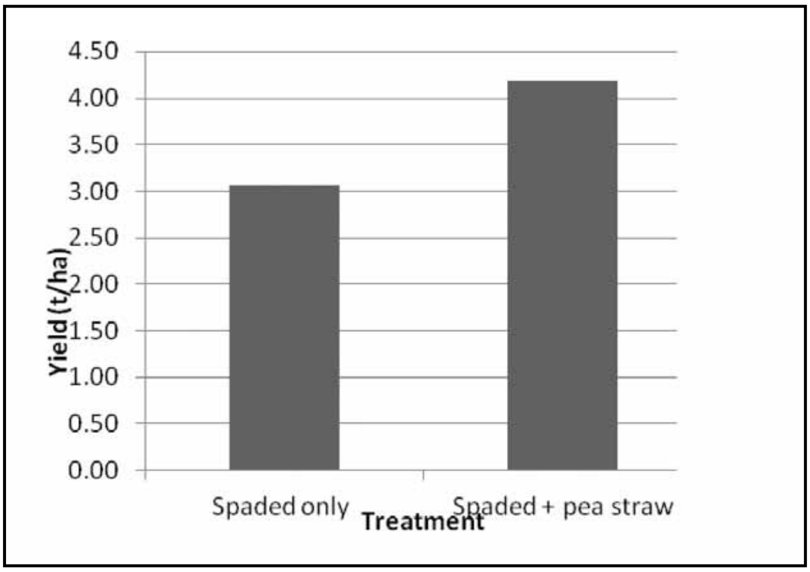


Figure 7 Dahlitz wheat yields, December 2011

Soils

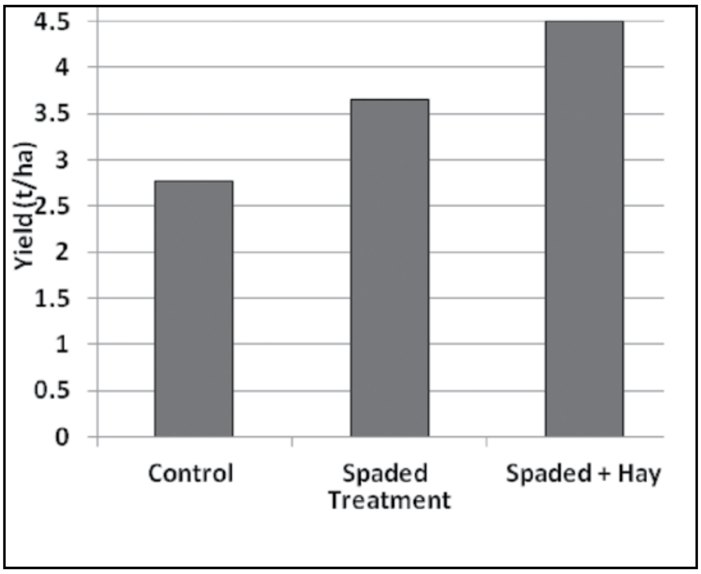


Figure 8 Treloar wheat yields, December 2011

Soil Health

Soil structure: Whilst the initial soil modification treatments involve significant soil disturbance, there is potential for long term structural improvements through the addition of clay and organic matter to the sandy A horizon.

Disease levels: The increased dry matter production resulting from the soil modification treatments may increase fungal disease pressure.

Chemical use: There are a number of effects of soil modification on weed management. The first is more even weed germination by addressing water repellence on sandy soils. This allows for more effective knockdown herbicide applications. The impact of spading on weed germination has been variable with an increased germination of grass weeds on some sites.

Soil nutrients: Increasing the clay and organic matter content in A horizons using these treatments can increase the nutrient and moisture holding capacity. If B horizon material which has high carbonate content is brought up by the treatment it can reduce nutrient availability.

Tillage type: The initial soil modification treatments require full soil disturbance to a depth of at least 15 cm. However by overcoming the water repellence in the A horizon through the addition of clay there is a reduced need for mixing the profile by cultivation.

Ground cover or plants/m^2: The soil modification treatments resulted in large increases in surface cover and crop biomass production. This is very important for reducing wind erosion risk on such fragile sandy soils.

Water Use

Water use efficiency: By increasing effective rooting depth of crops through soil modification there is potential to improve water use efficiency. However these demonstrations support results from earlier work where large increases in biomass production from soil modification treatments have not always been reflected in increased grain yields. Further investigation in required to quantify what is driving the relationship between biomass and yield following soil modification.

Resource Efficiency

Energy/fuel use: In the past incorporation of clay material after clay spreading and delving required multiple workings with a cultivator to be effective. Spaders are able to incorporate clay material and other soil ameliorants effectively to a depth of 30 cm with a single pass, significantly reducing the fuel requirement for modifying soils in this way

Social/Practice

Clash with other farming operations: Soil modification treatments are ideally applied as early as possible before the paddock is sown. This is to ensure effective incorporation of the clay and organic matter and give the modified soil profile the longest possible time to "stabilise" following treatment. Green manuring treatments are costly as the crop is unable to be harvested. However they can increase the nutrient and organic carbon in the soil profile as well as provide another weed control strategy. As the processes involve significant soil disturbance there is a high risk of wind erosion on the sites if adequate surface cover is not established rapidly. This can be difficult to do in late spring and summer.

Labour requirements: Soil modification operations require specialised equipment i.e. delver, spader. For most growers this means contacting out this work which, due to demands on contractors, can make it difficult to get the job done at the optimum time.

Economic

Infrastructure/operating inputs: Soil modification works are expensive. Delving costs between $125 and $185/ha with spading costs around $250/ha. The expected returns need be able to justify the costs of the operation.

Acknowledgements

The authors would like to thank the landholders involved in this trial; Gus Glover, Chris Will, Ed Hunt, Terry Young, Mick Dahlitz and Peter Treloar. Also funding bodies including GRDC, the South Australian NRM program and the Australian Government Caring for our Country Program

Dahlitz, Pillanna and Treloar, Edillilie - supported by the Lower Eyre Ag Development Association (LEADA).

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