A Journey in the Application of Research into Subsoil Manuring in the High Rainfall Zone of Victoria

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Abstract
Yaloak Estate at Ballan in Victoria's HRZ began the journey of investigation into how to realize the productive potential of the property 25 years ago. Cropping on raised beds in the 1990's led to dramatic yield improvements but we still weren't capturing the full water use potential that our climate could deliver. Wheat crops reliably yielding 8-10t/ha was our goal. Research commenced around 2000 and has been focussed and ongoing ever since. Hostile sodic sub soils were rapidly identified as the major impediment, so the means of ameliorating these became our goal. Subsoil manuring (SSM) using high rates of organic amendments injected into the interface of top soil and subsoil has delivered many of the gains we had hoped for and Yaloak now has the machinery and expertise to do this on a large scale. However, the research journey of understanding the specific subsoil issues within paddock, property and region and how they may be fixed, continues.

Keywords
Subsoil constraints, soil dispersion, sodicity.

Introduction
This paper aims to outline the journey taken by a farming business to apply research into SSM to improve the profitability of its pasture and cropping systems.

One of the main soil limitations for many cropping systems in Australia is often badged as subsoil constraints. Subsoil constraints penalise yield in both pasture and cropping systems by increasing the risk of temporal water logging, reducing the availability of soil water and nutrients for plant uptake and by reducing the efficiency of soil nutrition through imbalances in subsoil pH. The main subsoil constraint that is limiting yield in the high rainfall zone of Victoria (>500mm) is sodicity.

The predominant soil type at Yaloak is best described as a duplex Sodosol (Isbell 2002) made up of a basalt clay-loam topsoil over heavy sodic clay. This soil type is prone to water logging if not appropriately managed with surface drainage systems such as raised beds. The highly dispersive nature of the subsoil inhibits root growth and therefore the availability of nutrients and subsoil water to plants.

Methods
Catalyst for the adoption of subsoil manuring for the management of soils at Yaloak Estate
After the development of arable areas at Yaloak using raised beds in the 1990's the focus shifted towards the next yield limiting factor: hostile subsoils. In the early years of oilseed and cereal cropping at Yaloak yield penalties were often observed in a dry spring when crops began to suffer from heat and moisture stress. The effect of a dry spring was amplified by the water requirements of heavy canopy crops that were grown in favourable cool growing conditions over autumn and winter with no shortage of topsoil moisture and an abundant supply of mineralised nutrient from the fertile basalt loam topsoil. Consistent topsoil moisture through winter, good soil nutrition coupled with poorly structured and dispersive subsoils meant that crops grown at Yaloak would often develop shallow root systems which were not able to access water and nutrients in the subsoil. This was the most significant factor that was penalising yield at Yaloak.

Deep ripping in dry conditions to maximise subsoil fracturing was used in an effort to improve the movement of air, water and plant roots through the subsoil, although the effects were often only short lived as the dispersive nature of the subsoils would cause the newly open pore spaces to close over again within the first production year after ripping. Yield benefits from this practice were not often seen after the first twelve months. Surface applications of soil amendments like gypsum were used but were not effective in amending the subsoil which lies between 150-350mm below the surface.

Our efforts were directed to investigating new ways in which to improve the structure and water holding capacity of our subsoils. In 2005, Yaloak commenced a three-year ARC linkage program with Assoc. Prof. Peter Sale of La Trobe University to investigate ways of improving the performance of hostile subsoils. This project included the development of a two tine deep ripper designed to inject high volumes of organic material to a depth of 400mm.

The results of the research were outstanding with yield increases over three years ranging between 55% - 70% and gave great encouragement to pursue the application of the technology and the development of machinery capable of treating commercial sized areas.

Barriers to adoption of subsoil manuring

In the vast majority of publications relating to SSM it is said that one of the main barriers of the adoptions of SSM is that there is no commercially available machinery capable of treating large areas. The cost of developing such machinery that is capable of working on a broadacre scale has been inhibitive to the uptake of the technology. There were little to no preceding machinery concepts that were easily adapted to the task of injecting high rates of organic material to depths ranging from 300-400mm into dense clay subsoils.

The cost and availability of suitable soil amendments such as poultry litter has also been a significant barrier to the adoption of the technology. The main drawback of using the traditional rate of 20t/ha of poultry litter is the cost of transport of the amendment. Rice hull based poultry litter (common bedding material used in Victorian broiler sheds) has a bulk density that ranges between 0.35-0.45t/m^3. Because of the high volume of material required to treat large areas it is often necessary to source material from multiple suppliers and different locations, which makes it difficult to control the quality of material and cost of transport.

Understanding the concept of SSM in terms of its application and the science behind its success or failure in a variety of soil types with varying subsoil hostilities across multiple trials and research projects has also been a significant barrier to the adoption of the technology by growers.

Evolution of machinery

The first machinery for SSM developed by Yaloak in 2005 was relatively low tech, the machine was built on farm using a trailing belt spreader body adapted to discharge product into two steel pipes mounted behind deep rippers at 1.7m apart. Similar machinery was developed around the same time in a joint effort by Southern Farming Systems (SFS) and the Victorian Department of Primary Industries (DPI). Both of these machines were designed for trial plot purposes and were not suitable to treat large areas.

The first commercial sized prototype was built in 2010-2012 by Yaloak at Derrinallum and Ballan Victoria. This machine consisted of deep ripper bar with six deep ripping tines with a working width of 6m. The product was delivered through an air system from a trailing manure cart.

From 2012-2015 the 6m prototype underwent many different changes and modifications to improve its operating speed, application rates and reliability. These were first tested on a small 2m three-point linkage prototype that was developed by Yaloak to test different metering and air delivery systems. This 2m machine has since been modified to be used for establishing SSM trial plots.

This leap forward in productivity and the learnings that were obtained by Yaloak through the development of both the 6m and 2m prototypes encouraged the design and build of a second commercial sized machine for Yaloak by Dunstan Engineering. This machine has a working width of 8m and a material capacity of 50m^3, it has a field capacity of 3-3.5ha/hr and is capable of handling a variety of organic soil amendments such as poultry litter, green waste compost, pelletised product and alternative amendment blends using various agricultural inputs such as lime, gypsum and inorganic fertilisers.

The machine is drawn by a 600hp four-wheel drive tractor. The control system has certain level of automation which helps to minimise downtime caused by calibration issues or material blockages caused by operator error. The system that has been developed over the past three years with the intention of enabling the machine to handle both variable rate and variable depth applications of material in the future.

Results of on farm trials

Partnered research

The original trials conducted at Yaloak in partnership with La Trobe University in 2005-2007 saw yield increases ranging from 55%-70% over three years (Gill *et al.*, 2009). The authors concluded that the increase in yield of the plots with organic amendment treatments above control was attributed to the supply of subsoil nutrients and to the increased uptake of subsoil water that was made possible by the improvement in subsoil structure (Gill *et al., 2009).* The improvement of subsoil structure and subsequently plant available water (PAW) was said to be the result of increases in macroporosity and saturated hydraulic conductivity in the subsoil within the first cropping cycle (Gill *et al.*, 2009).

In 2009 Yaloak was again engaged with trials run by La Trobe University and the DPI. The trials were established in three locations in south west Victoria including property owned by Yaloak at Derrinallum. These trials looked at rate responses of incorporated poultry litter, ripping only and nutrients matched to the full rate (20t/ha) of poultry litter. Once again, the yield responses were outstanding with 20t/ha of poultry litter producing an extra 4.8t/ha of estimated wheat yield above control in 2009, 2.4t/ha above control in 2011 and 4.1t/ha above control in 2012 (Sale *et al.*, 2012).

Broadacre applications

The significant increases in yield that were demonstrated by the trials run at Ballan and Derrinallum between 2005-2009 provided encouragement for the rapid adoption of the technology by Yaloak. On the completion of the first large prototype in 2012, Yaloak began its first paddock scale applications of SSM. The team were meet with significant challenges in 2012 relating to teething issues with the machinery which slowed the process down followed by a very wet autumn in 2012 which inhibited timely sowing in autumn. Subsequently no data was collected in the first year. Subsoiling of the first paddock concluded in 2013 and the paddock was sown to canola, the yield increase on control was 80% over 60ha.

The results from the 2013 canola crop encouraged Yaloak to begin a large-scale SSM program covering some 500 ha on its Ballan property from 2014-2015. This was the first time that SSM had been conducted on such a large scale. The 2014 and 2015 seasons were exceptionally dry years with minimal subsoil water and very hot conditions during grain fill which checked yield potential in both treated and untreated cropping paddocks. The expectation of the significant yield increases that were seen previously in smaller trial plots were not met in the first two years post treatment at Yaloak.. This was largely due to the lack of significant rainfall events in 2014 and 2015.

Although many of the earlier small plot trials indicated possible yield increases of 55%-70%, Yaloak has observed the yield advantage of broadacre applications to be consistently within in the range of 20%-45%. This is due to a variety of factors that do not often affect small plot trials such as drainage impediments, spatial distribution of frost, hail and crop lodging resulting from damaging rainfall. One of the main factors affecting the performance of SSM is the spatial distribution of subsoil dispersion, which was not very well understood at the time when the large areas were treated in 2014-2015.

On farm research and trial work

Since 2005 Yaloak has invested significant time and resources into furthering our understanding of the soil constraints that are penalising yield in both our pasture and cropping systems. With a focus on training our staff to better understand these constraints we began to put together systems and equipment for soil sampling and testing to be used in future on farm research projects and for our own due diligence when assessing sites for subsoil amelioration. Putting these systems into practice in 2015, our staff worked with Declan McDonald of SESL in an on farm project to characterise soil types and identify soil constraints on the property.

Private research conducted in 2016 on behalf of Yaloak by Dr Mohsen Fruzangohar looked at identifying possible causes for significant yield variations across two paddocks at Yaloak. The yield variations were observed to be consistent across historical yield maps and appeared to correlate well with EM38 data that was collected in February 2015. In 2015 the most significant yield variation was observed in a paddock that had been subsoiled in the previous year, within 200m there was a difference of 7t/ha of wheat between two large areas yielding 9t/ha and 2t/ha respectively.

The main conclusion of this research was that spatial distribution of subsoil dispersion is the most likely reason for the observed yield variations between the high and low yielding areas (M. Fruzangohar. Personal communication.).

Current research

1. On farm controlled environment trials (2017-2019): The trial uses large reconstituted soil tubes to compare various SSM treatments in a standardised soil and climate environment. The eight treatments under comparison over two soil types have been selected with the following aims in mind;
    - To lift the productivity of the "poor" dispersive subsoils as identified in Mohsen's report.
    - To test gypsum efficacy when combined with both inorganic (fertiliser) and organic nutrients
    - To identify cheaper alternate amendment options than chicken litter for lifting productivity on both poor and good soils.
2. University of Adelaide: In 2018 Yaloak commenced an Innovations Connections research project with Prof. Mike McLaughlin, Senior Research Fellow Pichu Rengasamy and Research Fellow Ivan Andelkovic. The aim of this research was to identify the specific constraints of the poorer performing and dispersive subsoils and to assess the effectiveness of possible solutions using blended amendments.
3. GRDC Project in conjunction with Federation University (2019) – "*Using biosolids to overcome subsoil constraints in Victorian grain-growing areas*": Yaloak is partnered to this project as a site host for the trials and will be establishing private trials to assess amendment responses alongside the Federation University trial site.
4. In-house on farm trials (2019): The amendments to be tested in this trial will include various soil amendments blended with green waste compost.

Conclusion

Subsoil manuring has been proven to increase grain yield and dry matter production in crop and pasture systems at Yaloak Estate. The findings of numerous research projects both on and off farm have improved our understanding of the mechanisms driving the yield response we are seeing in our soils. These findings are becoming the catalyst for a changed approach to subsoil manuring at Yaloak, including targeted applications of subsoil amendments based on the known distribution of dispersive subsoils mapped by EM38 and historical yield maps.

The journey of the adoption of SSM as a practice has required significant input from the business both in the development of prototype machinery and facilitating inhouse and industry research trials.

References

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