Lower Eyre Agricultural Development Association

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Case-Studying successful management of soil acidity on Lower Eyre Peninsula, 2015

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- **Soil sampling undertaken on Lower Eyre sites in recent years through DEWNR and EPNRM funded projects identified an average acidification rate of around 0.4 pH units in 4 to 5 years.**
- **Previous estimates of lime required to offset soil acidification under agricultural systems for this region have been in the order of 80 to 150kg lime/ha/year.**
- **With higher intensity cropping, and consequently higher inputs of nitrogen fertiliser, it is suggested that this figure might now be in the order of 200 to 250kg lime/ha/year.**
- **If farming practices remain the same indications are that without the application of appropriate rates of lime the area affected by acidity will increase.**

Introduction

More than 178,000 hectares of soils on Lower Eyre Peninsula are susceptible to acidification that can negatively impact agricultural production. These are predominately ironstone soils south of Cummins and coarse shallow sands on clay near Ungarra/ Cockaleechie. Soil acidification is a natural process but is accelerated with agricultural practices such as crop/hay removal and use of high nitrogen fertilisers.

These case studies, compiled under LEADA's National Landcare Program (NLP) funded project, document the experience of two Lower Eyre Peninsula farmers in identifying and successfully treating acid soils on their properties. These studies have captured historical soil tes data, paddock yield maps, landholder observations and "real time" pH mapping data to identify changes to soil pH and production as a result of their treatments, and to document future management strategies for the site.

Case Study 1.
Mark and Tamara Modra

Location:
"Mondalee", Strawberry Hill Road, Edillilie

Farm enterprise:
Mixed grain and sheep production.

Average Annual Rainfall: 475 mm

Site Description and Identifying the Issue

Mark and Tamara Modra are partners in a 1920 ha family cropping and grazing farming enterprise with properties located at Yeelanna, Edillilie and North Shields.

The study site (Padddock 2) is a 56 ha gently undulating paddock consisting of ironstone loamy soils, coarse shallow sand over clays and red brown earths (Figures 1 and 2). The ironstone loamy soils and sands are prone to acidification whilst the red brown earths are alkaline with fine carbonate (lime) present in the soil profile at a depth of around 40 cm.

Mark has observed a large variation in yield across different soil types in the paddock depending on the season. He says that crops don't finish well on the ironstone and sandy soils in season with a dry finish and that waterlogging is a major production constraint in wet years. He feels that soil acidity is having an impact on crop root development which is resulting in less competitive crops and also considers that soil acidity is reducing root nodulation on legume crops.

Figure 1. Low production shallow sand on poorly structured clay

Figure 2. High production red brown earth.

Prior to 2005 the site was two separate paddocks with a fence dividing it north/south through the middle. Since this time the fence has been removed making one paddock. However due to differences in soil type, the western and eastern halves have had different liming histories with nil lime in the western half and up to 4 applications in the eastern half.

Historical Monitoring and Results of Treatment

A monitoring site established in 1970 on the eastern side of the paddock provides data illustrating acidification and the impact of lime applications over a 40 year timespan (Figure 3). Sampling in 1970 showed pH (CaCl2) values of 5.1 in the 0-10cm layer, pH 5.0 in the 10-20cm layer and 5.4 in the 20-30cm layer.

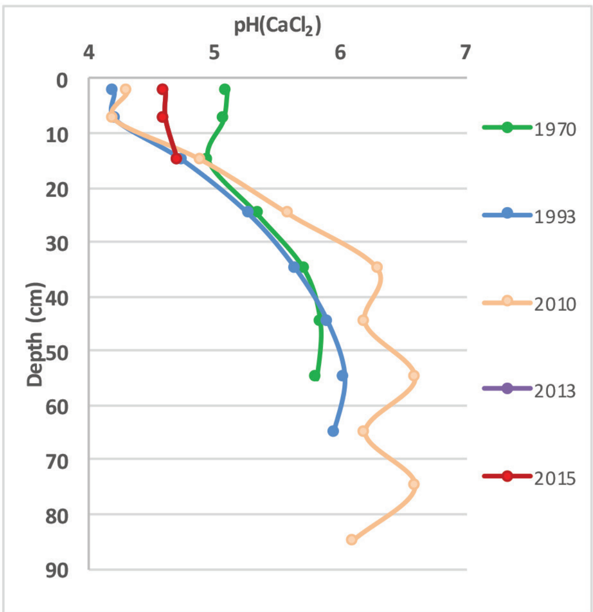


Figure 3. Change in soil pH over time at Modra's monitoring site.

The Modra family purchased the property in 1990. Soil samples from the site in 1993 recorded levels pH ($CaCl_2$) of 4.2 in the 0-10cm layer and 4.7 in the 10-20 cm layer. Mark applied lime (2.5 t/ha) on the eastern half of the site in 1995. Soil sampling in 2010 delivered similar 0-10 cm pH levels to 1993 with 10-20 cm pH values increased to around those of 1970. This suggests that acidifcation occurred more rapidly in the 0-10cm layer than the 10-20 cm layer and that Mark's application rate of 2.5t/ha in a 15 year period was not sufficient to maintain pH at desirable levels in this layer. Mark again applied 2.5 t/ha of lime to the eastern half of the site in 2012. Soil sampling in December 2013 showed that the lime applications had lifted surface pH to 4.6 ($CaCl_2$), however this was still below the desired surface pH value of 5.5 ($CaCl_2$).

As Mark was growing beans in the paddock in 2015 he was concerned that soil acidity would impact on crop root nodulation. He applied a further 2.5 t/ha to the eastern half of the site in January 2015 to try and bring pH in the 0-10 cm layer above 5.5 ($CaCl_2$).

Composites of harvester grain yield maps spanning a number of years (appendix 1) confirmed the yield variability across soil types and seasons. From these maps Mark was able to broadly identify low, medium and high production zones within the paddock and in March 2015 soil sampling was undertaken along transects in these zones. Field analysis of these samples identified that the worst producing areas of the site broadly correlated to the shallow coarse sands on clay, with the loamy ironstone soils having moderate production and the best producing areas being the alkaline red brown earths.

Laboratory analysis of pH ($CaCl_2$), electrical conductivity (a measure of salinity) and exchangeable cations was undertaken on all soil samples with an analysis of major nutrients, trace elements, organic carbon, boron and PBI (phosphorus buffering index) also conducted on 0 -10 cm samples (Appendix 2). Mark's history of applying adequate nutrition for expected crop yield is reflected by the soil test results with nutrient levels in the 0-10 cm layer of the medium and high production zones above those generally considered adequate for crop growth. Surface organic carbon levels are in a range which suggests good inherent fertility and PBI values indicate that crop production is unlikely to be constrained by phosphorus tie-up. Exchangeable sodium and salinity values were also low in these zones.

Soil pH values on the high production zones were neutral to alkaline ($>$ 6.0 pH $CaCl_2$) throughout the profile. Although results show that Mark's lime applications have had some effect in arresting further pH decline on the medium production zone, they were only enough to combat annual acidification and in March 2015 surface pH was still below the level of 1970. Furthermore subsurface pH levels had dropped by 0.2 pH units. This may be because too little time had elapsed between the lime application in January and sampling in March for the lime application to effect pH change. In the low production zone surface pH values were also acidic. Higher pH values in the 10-20 cm layer compared to the 20-40 cm layer on the limed area however suggest that Mark's previous lime applications have been successful in treating acidification of this layer. Phosphorus and organic carbon levels in the 0-10 cm samples from the low production zone were also higher than expected given surface soil textures. This might reflect low fertiliser use efficiency and microbial activity due to low soil pH.

Paddock Scale pH mapping

With support from the Agricultural Bureau of South Australia "Innovative technologies for managing soil acidity" project funded by the Australian Government National Landcare Program, pH mapping of the site was undertaken using a Veris pH detector probe mounted to a quadbike (Figure 4).

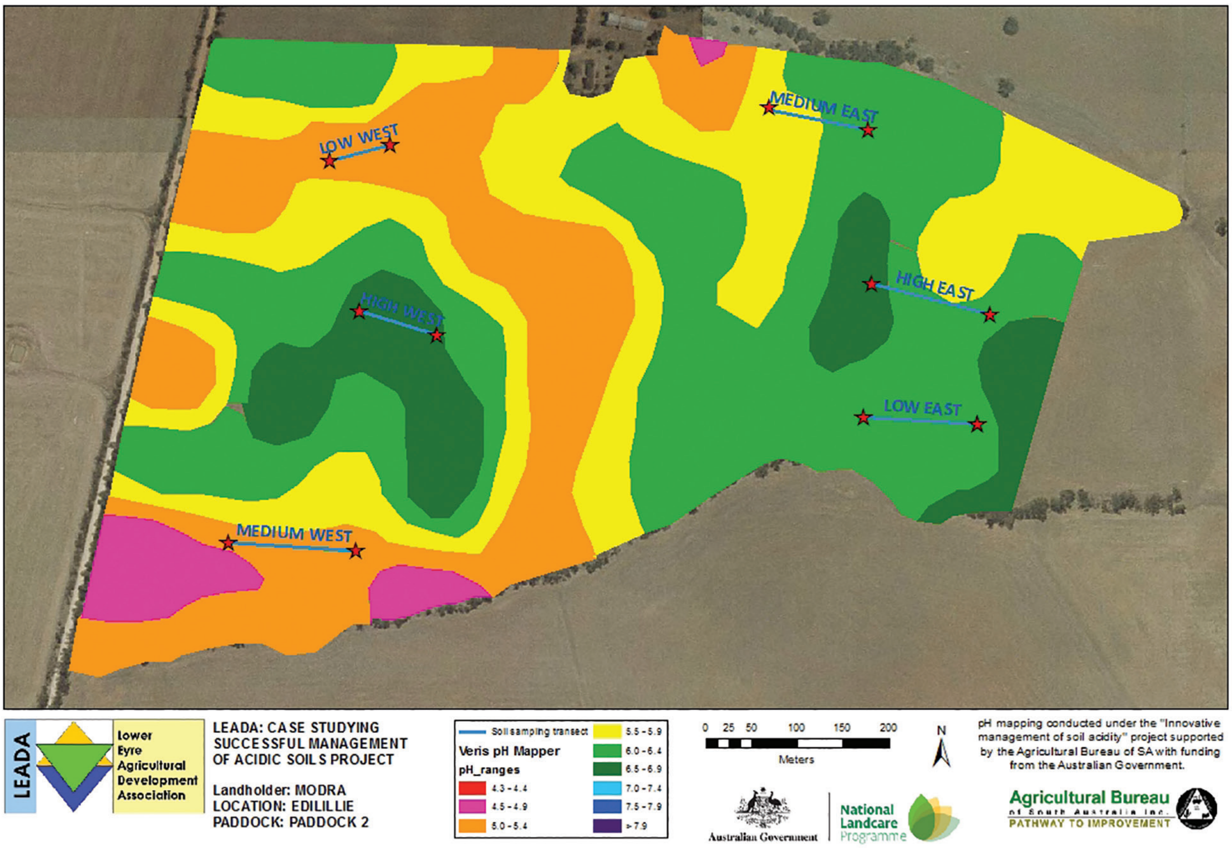


Figure 4. Modra pH map (Western half unlimed, eastern half limed).

The pH mapping identified that only 15 ha (27 % of the total paddock area) has surface pH currently below the target pH of 5.5. Mark has been applying a uniform rate of 2.5 t/ha on the eastern half of the paddocks. If Mark were to apply a uniform application rate of 2.5 t/ha across the whole 56 ha paddock the total lime requirement would be 140 t with a total application cost of $4480. By using the pH mapping data however, Mark can target applications to only the 15 ha that are below 5.5, with a total lime requirement of 17 t costing $544. If the cost of mapping is added this gives a total cost for the liming application of $1008 delivering a saving of $3472 (Table 1).

	Uniform Paddock Rate	Tailored rate from paddock map
Area requiring lime (ha)	56	15
t/lime required	140	17
Cost lime ($12/t)	1680	204
Cost freight and spreading ($20/t	2800	340
Cost of Mapping ($10/ha)	-	560
Total cost	4480	1008
Saving ($= cost blanket rate - cost of mapping - adjusted cost)	$3472	

Table 1. Cost of lime application; Modra Site.

- **Previous experience on these soils suggests that to increase pH by around 1 unit in the 0-10 cm layer from a starting pH of around 4.5 would requires an application of around 3.0 t/ha of high quality lime.**
- **If we use this rate as a standard multiplier, to raise surface pH to the target 5.5 those areas of the paddock in the range 4.3 to 4.4 would require 2.5 to 3.0 t/ha.**
- **Areas in the pH range of 4.5 to 4.9 would require around 2 t/ha lime.**
- **Those in the pH range 5.0 to 5.4 would require 1 t/ha.**

Discussion of Results and Conclusions

By investigating and characterizing the soil profiles in each of the production zones Mark was able to identify that the poor producing areas are coarse shallow sands which tend to be highly leaching and often have bleached A2 horizon or ironstone gravel above the clay layer. These soils tend to have low inherent fertility, poor nutrient holding capacity and are unable to readily buffer pH change. His best producing areas were largely alkaline red brown earths with friable loamy surface soils on well-structured clays. With more clay in the 0-30 cm layer these soils have higher inherent fertility and are better able to buffer pH change (i.e. acidify more slowly) than the soils in the low production zones, however through high input agricultural production they may acidify over time. The medium production zone on the unlimed western portion of the paddock consists of a gravelly sand over dispersive red clay whilst the medium production zone on the limed eastern half of the paddock is an ironstone loam.

Soil analysis at this site has provided Mark with some confidence in his nutrition strategies and provided sufficient data to evaluate changes in soil pH over time. He has also gained some understanding of the length of benefit from lime applications. In both the high and low production zones, field pH measurements in the 0-10 cm soil layer were higher on the limed area than the unlimed area. In the low production zone the surface pH of the area that had been limed was also higher than the subsurface (10-20 cm) which could reflect an increase in pH from liming. On the medium production zone however, pH was higher in the unlimed area than the limed area which reflects the variation in soil type for the medium production zone.

The pH mapping has provided Mark a more complete understanding of spatial variability and when compared to yield maps identifies the relationship of soil type to productivity. This map added an extra layer of information to the site reflecting and more clearly delineating the variation in soil types and soil pH values identified by sampling. The pH map also reflected the liming history of the paddock with results from similar soil types generally being higher and less variable on the limed areas than the unlimed. This has led him to conclude that further acidification may have potential impacts including; aluminium toxicity; poor crop competition and poor legume nodulation which are key drivers for his decision to counteract soil acidity.

While Mark considers that there has not been an immediate yield response to lime application, on soils prone to acidification he is implementing liming strategies so as to remove soil acidity from the list of factors potentially limiting current production and ensure that problems (particularly in the subsoil) do not develop in the future. Mark considers that the key to cost- effectively managing soil acidity is to identify soil pH levels through soil testing and to determine the distribution within and between paddocks. The data gathered under this project supports his own observations of more competitive crops and better legume nodulation on limed soils compared to unlimed ones and has given Mark some confidence and that his “blind faith” in combatting soil acidity is starting to bear fruit.

Recommendations.

Mapping soil pH at the site has provided more data which well reflects the liming history on the site and supports the development of cost effective liming strategies. On this paddock, due to the low tonnage of lime required at present and the short amount of time elapsed between the January 2015 lime application and the pH mapping in June, Mark has decided that the best management strategy is to continue to monitor pH levels over the next 2 to 3 years and apply lime when a large proportion of the paddock is approaching pH 5.0 ($CaCl_2$).

Where to from here?

Although the information gathered for this project has been able to assess the impact of Mark’s current soil acidity treatments Mark sees a number of challenges and opportunities for strategic and effective management of soil acidification at the site. Mark is concerned about the potential for acidification of deeper soil layers on the low buffering and highly leaching soil types and the difficulties and costs of addressing this should it occur. He would also like to be able to further quantify the impact of liming on crop yields. Mark will continue to monitor soil pH across his properties, liming paddocks to bring the surface pH to the target 5.5 ($CaCl_2$) and then continue a maintenance liming program where necessary. Having treated the soil acidity at this site Mark is interested to investigate how to best manage nutrition (particularly trace elements) to best reflect soil variability.

Case Study 2.
Ben and Brooke Pugsley, "Glenora Ag."

Location:
Cockaleechie Road, Ungarra

Farm enterprise:
Mixed grain and sheep production.

Average Annual Rainfall: 450 mm

Site Description and Identifying the Issue

Ben and Brooke Pugsley are partners in a 1350 ha family cropping and grazing farming enterprise with properties located at Ungarra. The study site (Winnow/Flat Paddock) is an 83 ha paddock comprising a generally flat northern half and a gently sloping southern half. Soil profiles in the northern half comprise of loamy red brown earths and acidic coarse sands to sandy loams on poorly structured clay (Figures 5 and 6). The southern half of the paddock is a shallow red brown earth on quartzite rubble.

Ben's investigations into the impact of soil pH began in 2009 when Ben was curious as to why crops were not performing as well as expected on a leased property at Moody Tanks. He was inspired to look at soil acidity by his neighbour Bill Adam's who had tried liming acid soils on his property with good effect. Bill's comment to Ben was that although "liming acid soils may not turn a paddock into the best on the farm, it will make a poorly producing paddock pay for itself". Ben bought a field pH kit and during 2009 tested the soil pH of many paddocks across his property with the field kit returning pH values between 4.5 and 5.0. During the same year Ben also sent a soil sample from the case study site for laboratory analysis of nutrition and pH. Results of this analysis returned a pH value of 4.9 ($CaCl_2$) for the paddock. Ben considers that the major production issues on the site are found on the sandy areas which have bleached A2 horizons, low nutrient retention and low pH buffering capacity. These issues are evidence by poor weed competition, poor crop growth and water logging in patches. Ben has observed that where soil acidity is an issue weeds are a major issue and he struggles to grow competitive barley and canola crops.

In the past the northern flat and sloping southern half of the site have been managed as two separate paddocks. Removal of an internal fence in recent years has resulted one larger paddock. Lime was applied at 3 t/ha to the northern part of the paddock in 2011.

Figure 5. High production loamy red brown earth.

Figure 6. Low production coarse sand on poor structured clay.

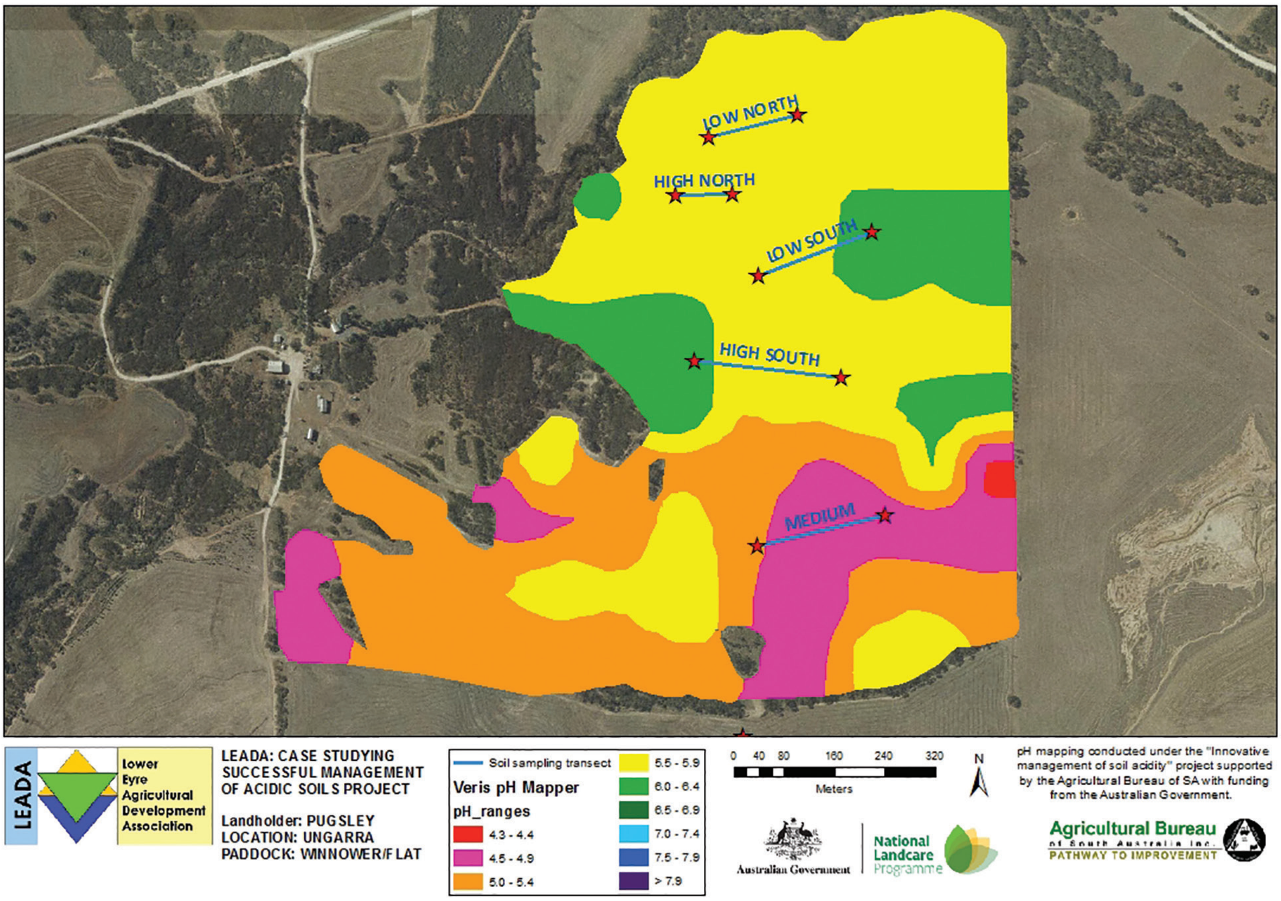


Figure 7. Pugsley pH map and soil sampling transects (southern half unlimed, northern half limed).

Historical Monitoring and Results of Treatment

Composites of harvester grain yield maps spanning a number of years were produced in March 2015. The maps were able to look at crop performance over a number of years compared to the paddock average yield and low, medium and high production zones were identified within the paddock (Appendix 3). Soil samples were taken in March 2015 along transects in these production zones. Field analysis of these samples identified that the worst producing areas of the site broadly correlated to the coarse sand over poorly structured clays at the northern end of the paddock and the highest producing areas correlated to the loamier brown earths which were generally more elevated and less prone to water logging than the sandier profiles. The rise in the southern half of the paddock consists of a shallow red brown earth that has moderate production.

Laboratory analysis of pH (CaCl2), electrical conductivity (a measure of salinity) and exchangeable cations was undertaken on all soil samples with analysis of major nutrients, trace elements, organic carbon, boron and PBI (phosphorus buffering index) also conducted on 0-10 cm samples (Appendix 4). Laboratory analyses showed moderate levels of nutrients on all transects. PBI values <30 indicate some potential for some phosphorus to be leached in the northern zones. Ben applied 2-3 t/ha of lime to the northern area of the paddock in 2011. Soil analysis in 2014 indicated that this lime application had increased the surface soil pH to 6.1 (CaCl2) on the high production zones and 5.8 (CaCl2) on the low production areas. However, when sampled in March 2015 pH in the 0-10 cm layer had dropped to 5.6 (CaCl2) on the low production and high south production zones and was much lower (5.0 CaCl2) on the high producing north transect. This suggests that the surface soil on northern high production zone is acidifying at a greater rate than in the southern high production zones and corresponding low production zone. The pH level in the subsurface (10-20 cm) layer of this transect was also low (5.2 CaCl2)

Paddock Scale pH mapping

With support from the Agricultural Bureau of South Australia project funded by the Australian Government National Landcare Program, the site was mapped using a Veris pH Detector mounted to a Can-Am (Figure 7).

The pH mapping identified that 34 ha (41 % of the total paddock area) has surface pH currently below the target pH of 5.5 (Figure 7). Ben was considering applying a uniform rate of 2.5 t/ha across the northern half (flat) area of the paddock. If he were to apply this rate across the whole 83 ha paddock this would require 280 t of lime with a total spreading cost of $6056 (Table 2). However, using rates targeted to the 34 ha of area identified by the pH mapping the total lime requirement is 73 t for the paddock. Taking into account the cost of the pH mapping this results in a total lime application cost of $3166 delivering a saving of $3490.

Discussion and Conclusions

The interaction between soil pH and weed control has been a key driver for Ben to investigate soil pH across the property and he now uses weed competition, herbicide effectiveness and crop performance as indicators of low soil pH. Ben considers that a key factor influencing the profitability of his system is the cost of weed control, particularly ryegrass. He has observed that applied herbicides which rely on some soil bound residual activity work more effectively on areas which he has limed. He considers that this may be a function of healthier crop growth and therefore more crop competition following liming. He also thinks that he is gaining a benefit from better herbicide efficacy. As a result of these observations Ben now checks soil pH if he notices a particularly good or poor result from herbicide applications.

The data gathered under this project has given Ben confidence in the impact that his lime applications have had and provides a starting point to devise management strategies for the site and other paddocks on the property. Ground truthing the production zones indicated by yield maps by targeted soil sampling has linked some of the yield variability to soil type and allowed some inferences to be made as to the expected rate of acidification and the likely soil pH response from a lime application. When compared to a composite grain yield map made across seasons there was also a correlation between yield and soil type. Ben has investigated the relationships between soil texture and organic matter and acidification rates and has learnt the importance of well buffered soils for reducing the rate of soil acidification. As a result of this he sees great value in retaining as much plant residue as possible on light textured soils to improve organic matter which will in turn improve soil structure, water holding capability, store nutrients and buffer pH change.

The pH map added an extra layer of information to the site, reflecting the variation in soil types identified through the soil sampling. The pH map also seemed to reflect the liming history of the paddock as when taking into account the different soil types the pH

	Uniform Paddock rate	Tailored Rate from pH mapping
Area requiring lime (ha)	83	34
t/lime required	208	73
Cost lime ($12/t)	2496	876
Cost freight and spreading ($20/t)	4160	1460
Cost of Mapping ($10/ha)	-	830
Total cost	6056	3166
Saving ($= cost blanket rate - cost of mapping - adjusted cost)	$3490	

***Table 2.* Cost of lime application; Pugsley Site.**

levels were generally higher and less variable on the limed northern half of the paddock than the southern unlimed area.

Recommendations

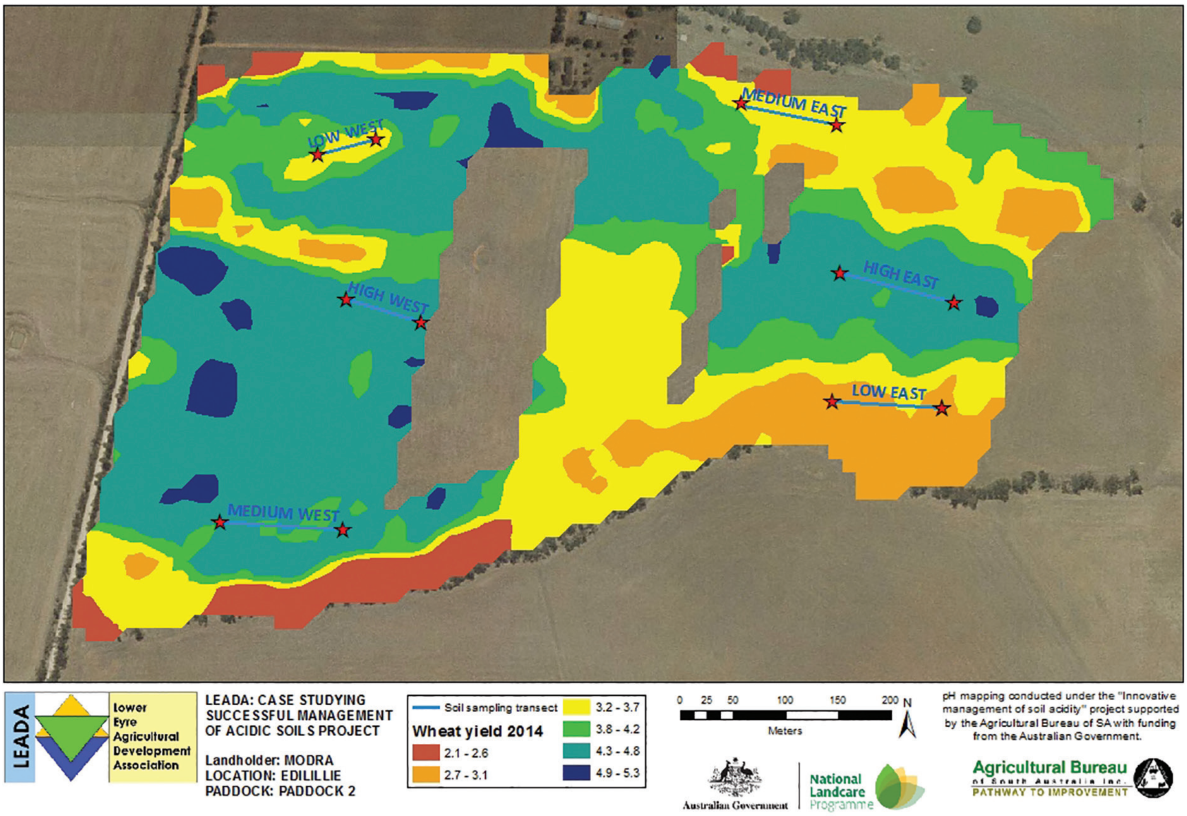
The pH mapping identified that most of the very low surface pH is in the unlimed area in the southern portion of the paddock. It is recommended that Ben apply lime to this area as soon as possible to bring surface pH values up to the target 5.5 (CaCl2). Following this application it is recommended that Ben monitor changes in pH with maintenance lime applications as needed.

Where to from here?

Ben considers that the knowledge gained through this project on the Winnower/Flat paddock is just a starting point for continuing to investigate and manage the impact of soil acidity on his property. Despite not seeing a direct correlation between lime applications and yield Ben is confident that he is getting production and agronomic benefits from treating soil acidity and feels that it is important for him to "get ahead" of the issue. He likens his approach to managing acidity to those landholders in the district who applied gypsum for managing sodicity 10 to 15 years ago and now have better structured, more productive soils as a result. He feels that compared to the cost of some of the other crop inputs liming is a cheap solution to give his crop its best chance even if the only benefit is increasing the competitiveness of crops against weeds.

APPENDICIES

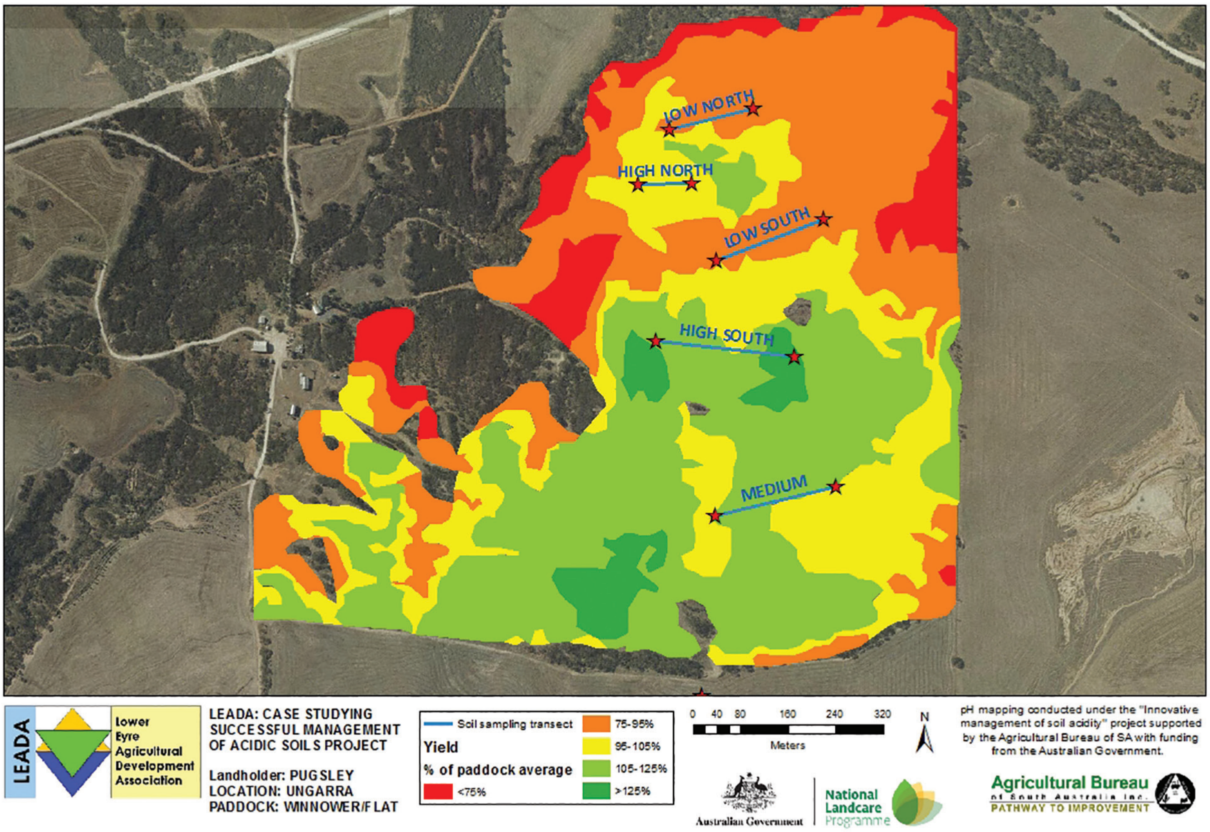
APPENDIX 1. MODRA PRODUCTION ZONE (WHEAT YIELD 2014)



APPENIDIX 2. MODRA SOIL ANALYSIS DATA

PRODUCTION ZONE	WEST (UNLIMED)							EAST (LIMED)					
	DEPTH	pH	EC	Organ-ic C.	CEC	ESP	PBI	pH	EC	Organ-ic C.	CEC	ESP	PBI
	cm	CaCl2	dS/m	%	cmol+/100g	%		CaCl2	dS/m	%	cmol+/100g	%	
HIGH - ALKALINE RED BROWN EARTH	0-10	6.4	0.169	1.61	20	2	85	6.2	0.131	1.78	11	1	54
	10-40	6.6	0.082	NR	27	2	NR	7.1	0.204	NR	25	2	NR
	40-80	7.7	0.160	NR	23	3	NR	7.7	0.160	NR	22	6	NR
MEDIUM WEST-(UNLIMED) Gravelly sand over dispersive red clay. EAST (LIMED)- Ironstone loam	0-10	6.9	0.180	1.43	20	1	78	4.8	0.072	1.29	6	2	62
	10-20	7.3	0.065	NR	16	2	NR	5.3	0.035	NR	5	2	NR
	20-40	7.5	0.122	NR	23	3	NR	6.8	0.091	NR	8	3	NR
	40-80	7.8	0.150	NR	22	6	NR	7.3	0.127	NR	8	4	NR
LOW - Shallow sand over clay	0-10	4.9	0.088	1.68	5	6	56	5	0.072	1.30	6	2	52
	10-20	6.1	0.070	NR	7	10	NR	6.4	0.130	NR	10	1	NR
	20-40	7.6	0.349	NR	19	17	NR	5.7	0.076	NR	9	2	NR
	40-80	8.1	0.530	NR	27	28	NR	6.3	0.100	NR	8	4	NR

APPENDIX 3. PUGSLEY PRODUCTION ZONES (YIELD COMPARED TO PADDOCK AVERAGE)



APPENDIX 4. PUGSLEY SOIL ANALYSIS DATA

Sample ID	PRODUCTION ZONE	Depth	pH	EC	Organic C.	Colwell P	CEC	ESP	PBI
		cm	CaCl2	dS/m	%	mg/Kg	cmol+/100g	%	
BP_Z1HS	HIGH SOUTH	0-10	5.6	0.08	1.47	70	6	5	39.2
BP_Z1HS	HIGH SOUTH	10-35	7	0.25	NR	NR	20	14	NR
BP_Z1HS	HIGH SOUTH	35-80	8.1	0.50	NR	NR	24	22	NR
BP_Z1HN	HIGH NORTH	0-10	5	0.04	0.83	23	3	2	13.7
BP_Z1HN	HIGH NORTH	10-20	5.2	0.02	NR	NR	1	5	NR
BP_Z1HN	HIGH NORTH	20-80	7.1	0.16	NR	NR	20	10	NR
BP_ZM3	MEDIUM	0-10	5.8	0.06	1.30	34	6	2	57.9
BP_ZM3	MEDIUM	10-30	6.6	0.10	NR	NR	14	4	NR
BP_ZM3	MEDIUM	30-80	7.5	0.21	NR	NR	13	5	NR
BP_Z2LN+S	COMBINED LOW	0-10	5.6	0.06	0.86	40	3	4	21.9
BP_Z2LN+S	COMBINED LOW	10-20	5.7	0.02	NR	NR	1	6	NR
BP_Z2LN+S	COMBINED LOW	20-30	7	0.03	NR	NR	1	9	NR
BP_Z2LN+S	COMBINED LOW	30-80	7.2	0.16	NR	NR	11	25	NR

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