USE OF PRECISION AG MAPPING TO IDENTIFY AND AMELIORATE pH VARIATION ECONOMICALLY

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This project focused on how to best ameliorate pH imbalances throughout the soil profile and spatially across singular paddocks.

Throughout the Upper North Agricultural Zone pH imbalance, more specifically acidity, has been identified as an increasingly prevalent constraint. Historically, much of the region's soils were buffered enough to withstand changes to pH due to a high clay content and low to medium rainfall. Modern farming practises, has accelerated acidification of our soils in the following ways;

- Intensified use of acidifying fertilizers containing nitrogen
- Incorporation of legumes which excrete organic acids as a means to better access phosphorous stores in the soil
- Increased intensity of production (i.e increased yields) and hence export of cations (positively charged nutrients)
- Continued leaching of cations down the soil profile with movement of water

This is now a well known and understood fact among growers in the region, with many following a lime program to combat the issue for several years now.

Recent research has found that following continued applications of lime to the soils surface, there is a difference in pH throughout the soil profile of limed paddocks, known as pH stratification. Lime is typically applied to the topsoil and will sometimes be incorporated with modern sowing systems (knife points). This helps to incorporate lime throughout the first ~5 to 10 cm's of the profile. However, localised work has found that lime is still only moving on average 2.5 cm's each season, pending rainfall amount and lime type. Therefore, our mindset around pH management may need to be adjusted, particularly with paddocks that have a lime history.

This case study aims to investigate the best methods of pH sampling both at individual sites and across paddocks, review our local lime sources and assessed the economic cost of liming vs. not liming.

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Words you will need to know.

pH - pH is the measurement of hydrogen ions within the soil solution and can have a large impact on the availability of nutrients to plants. The scale begins at zero, moving up to fourteen, with a value of seven being considered neutral.

Yield Limiting pH – A pH value that imposes a penalty to the yield potential of a particular soil, which is not related to water or nutrient availability of the soil in question. This can be due to either acidity or alkalinity and will vary between cultivars.

Acidity – A pH less than 7.

Alkalinity – A pH greater than 7.

Neutral – A pH of 7.

Solubility – The ability of a product, in this case lime, to dissolve in water and hence move down the soil profile with rainfall.

Particle Size – The size of individual particles of lime. Particle size is measured using the below increments and determined by running lime through a series of different sized sieves. As particle size reduces, solubility and ability to neutralise acidic soils increases. This is due to smaller particles having a greater surface area.
0 to 0.25 mm
0-26 to 0.50 mm
0.51 to 0.75 mm
0.76 to 1 mm
1.1 mm and greater

Chemical Stratification – Chemical stratification is defined by a large difference in soil chemical characteristics between top and sub-soil layers. In the case of pH stratification, it's the sudden change in pH. Typically, this is moving from alkaline conditions on the soils surface (0-5 cm's) where lime has been applied to acid conditions where fertilizers are added to the soil (5-10 cm's).

Lime – A highly alkaline product consisting of calcium carbonate, which when applied to an acid soil helps to raise the overall pH.

Calcium Carbonate - The chemical name for lime. This can be either as an agricultural liming product that is applied to soils to rectify acid soil conditions, or naturally present in soils, contributing to the soils alkaline conditions.

Neutralising value (NV) – This value indicates the ability of a lime source to neutralise an acid soil. The value is expressed as a percentage and indicates the amount of calcium carbonate which is present within the lime source. Products with a higher neutralising value indicate increased ability to neutralise acid soils (increase pH).

Effective Neutralising Value (ENV) – This value considers the percentage of calcium carbonate / magnesium carbonate in combination with the particle size of lime sources. When calculating lime requirement, rates need to be adjusted for a 100% ENV. For example, if your lime product has an ENV of 80% you need 1.2x to achieve a 100% ENV. In other words, a 1t/ha recommendation would be 1.2 t/ha of the natural product.

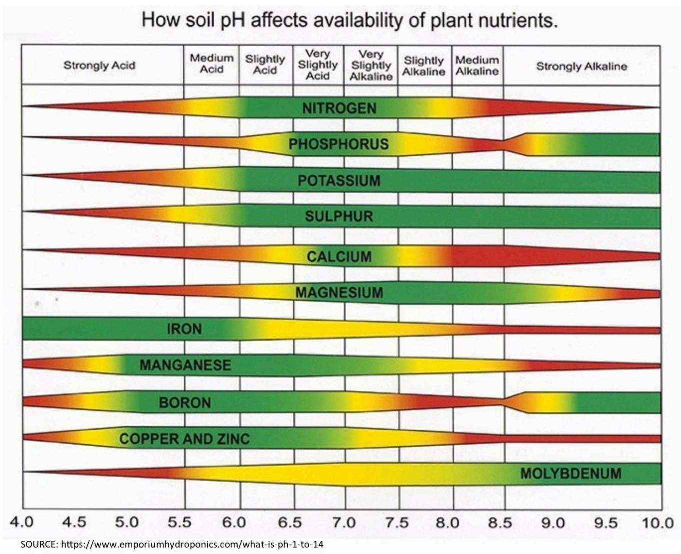


Figure 2. pH scale showing the availability of nutrients required for plant growth (AgroBest, 2017).

PH SAMPLING AN UPDATED METHOD

Soil pH can vary across paddocks, changing quickly across the landscape due to parent material, topography, and historical management practises. Across the upper north, east of 'the ranges' there are strong trends of calcium carbonate (free lime) rises where the pH is alkaline. These landscapes will commonly be paired with deep, fertile depressions, where acidity is commonly found within the same paddock. Alternately, west of 'the ranges' as you move closer to Baroota and Port Germain the dominant soil type is a dune swale system with a light texture. This area is naturally prone to soil acidification within the top soil due to the soils low cation exchange capacity (CEC).

In recent years pH sampling has advanced significantly, allowing us to spatially measure pH for the variable rate application of lime. The Veris Machine was the first technology which could economically map soil pH spatially. This technology measured soil pH 'on-the-go' using a dry electrode. This gave a pH reading in water, measuring approximately the first 3 cm's of soil. This sampling technique has a few short falls, which results in increased room for sampling error. Firstly, sampling is shallow and cannot identify an 'acid throttle'. Additionally, sampling pH in water may result in the 'salting effect' to skew results. If there is salt within the medium being sampled, the final pH reading can be pushed closer to neutral, incorrectly resulting in the conclusion no lime is required.

Sampling has since advanced to taking 'on-the-go' 0-10 cm cores which are bagged and sent to soil testing facilities. This allows for a pH reading in $CaCl_2$, which is closer to what plant roots experience in soil solution.

Recent work has looked to improve our understanding of pH sampling strategies, finding that testing in 5 cm increments to a depth of 20 cm's gains the most accurate snapshot of lime requirement, particularly in paddocks with a lime history. Testing following this protocol avoids a dilution effect of 'acid throttles' throughout the soil profile. Acid throttles refer to a sudden decrease in pH in contrast to above soil layers, which shock the growing plant roots upon entering the strongly acidic soil horizon soon after crop establishment. This is also commonly referred to as pH stratification.

Lime applications to the topsoil, in low to medium rainfall environments, typically corrects the top 5 cm's of the soil resource, leaving the soil resource beyond 5 cm's still acid. This is attributed to a combination of factors, including low rainfall and low solubility of the liming product. With poor movement of product, the soil resource is rarely receiving lime beyond the 5 cm mark, without physical incorporation. Additionally, with sowing fertilizers being placed within the 5-10 cm fraction, acidification is common to this area of the profile. Another issue is the under application of lime. If only a partial amount of the lime requirement of a soil is added, the product is all 'consumed' before making it very far down the profile.

If measuring 0-10 cm's in limed paddocks, the alkaline fractions in the 0-5 cm fraction is mixed with the typically acid fraction in the 5-10 cm's fraction. This leads to a dilution effect where the end reading is averaged to a neutral to only slightly acidic reading, mis-leading management decisions.

Acid throttles have also been found within the 10-20 cm soil fraction, therefore sampling to these depths is required to correctly identify lime requirement.

When sampling a paddock soil pH it is therefore important to understand the paddock is both variable across the paddock and down the soil profile and a soil sampling strategy that recognises this is essential to identify the required lime to restore soil pH to a more neutral level throughout the whole profile.

ALL LIME IS NOT THE SAME - LIME SOURCES

When making the decision of what lime to use, there are various factors to consider. The most obvious considerations include proximity to the farm, cost of transport and cost of product. However, there are also other factors including the solubility of the product, particle size and chemical make-up which will all determine the success of your lime application. There are four main options when choosing a lime type, with different limes suited to different applications.

Calcitic Lime – Rock Lime

This lime source is one of the most abundant minerals on earth, after quartz. It is typically colourless, white or grey when pure or yellowed when iron is also present within the source. This is a soft rock, which can be crushed easily.
Rock lime is formed independent of organisms. This type of limestone was originally present in solution (i.e. within a water source, typically sea water). As the water source dried up, the calcium carbonate becomes a 'lime mud' deposit on the floor of the seabed eventually then forming a soft rock, which we mine today.
Calcitic lime has a moderate solubility, which is strongly dependent on the particle size of the source. Typically, it is mined as rock lime and then processed through a series of crushing plants to reduce the particle size and hence improve the neutralising value of the product.

Dolomitic Lime – Dolomite

Dolomitic limestone is formed under the same principle as Calcitic Lime. The difference being that Dolomitic lime contains magnesium. Dolomite is considered the least soluble neutralising product, meaning it will take longer to neutralise an acid soil and typically have a low neutralising value. This lime source is well suited to scenarios where magnesium is required.

Coralline Lime – Seabed lime

Coralline lime is formed by sea organisms and hence is commonly referred to as seabed lime. Throughout the lifecycle of various sea organisms, calcium carbonate is drawn out of the sea water and used to form shells and bones. When these organisms then die the shells, bones and other carbonate rich body parts decay naturally, eventually turning to sand or mud. This mud source solidifies under pressure and becomes 'seabed lime'. This lime source has small particle sizes and is typically more soluble compared to all other lime sources so will work to neutralise the soil quicker. However, there has been no significant correlation found between seabed lime and increased movement of lime throughout the soil profile.

Lime Sand

As shells of organisms decay, the remaining product is lime sand. This lime source has a very low solubility and large particle size. Therefore, it will work to neutralise acid soils much slower in contrast to other lime types.

The purity of all the above materials will vary, as they are all natural products. Additionally, there is commonly a mix of lime types within quarries. For example, it is common to find a quarry with seabed lime mixed with dolomite. A lab sample of lime pits is required when deciding which lime source is best for your farming enterprise.

ACIDIFICATION IN MODERN FARMING SYSTEMS

Modern farming systems are the cause of acid soils in areas once considered predominantly alkaline or neutral. With increased production comes decreasing pH as outlined throughout this paper. Below is a table estimating the rate of soil acidification in modern farming systems. This takes into consideration fertilizer usage and export of cations via harvest products giving an end value to lime requirement to maintain pH long-term. This table demonstrates the on-going requirement of soil pH monitoring and lime application in our modern farming systems to maintain current yield potentials.

Land use	Mean annual acidification rate (kg lime / ha / year)
Low intensity grazing	30
Medium intensity grazing (some hay cuts)	100
High intensity grazing	150
Cropping pasture rotation	100
Intensitve cropping (some pasture, high N inputs)	200
Mostly continuous cropping (hugh N demand)	250
Continuous cropping (high leaching years)	350

So how much lime do I need and where should I put it?

A Precision Agriculture Approach to Lime Application Case Study

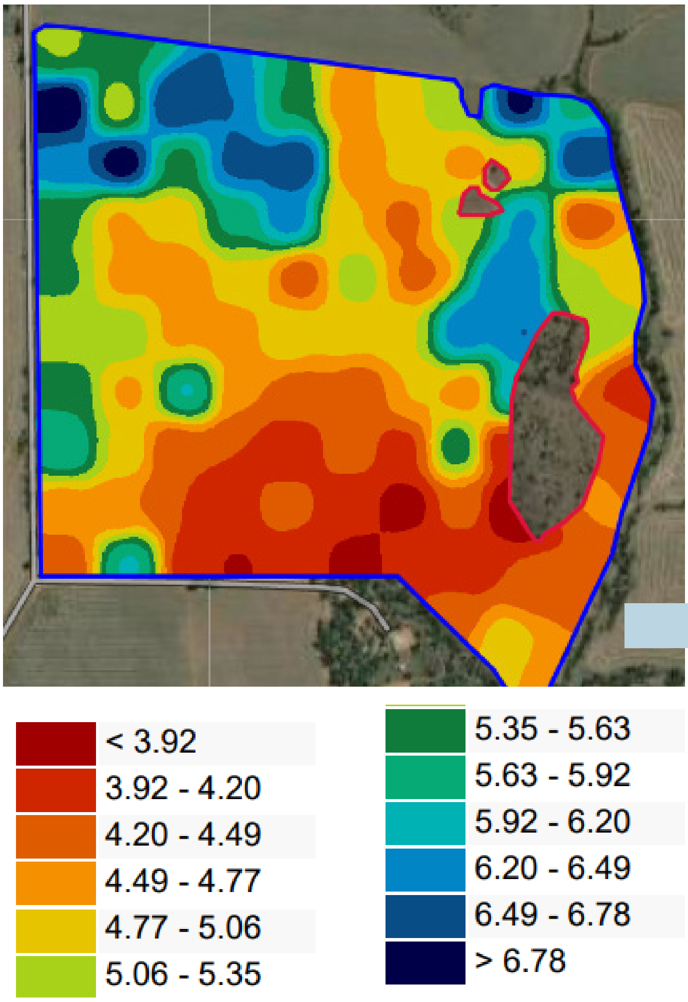
Farm details

Owner: Greg Durrent
Location: Huddleston, SA
Ave. Rainfall: 430mm

An economic case study of variable rate liming to match spatial pH changes across a paddock in the Upper North was completed on a 92 ha paddock that was initially pH mapped in 2015 (maps below) using a 1 ha grid sampling pattern to a depth of 10 cm's. Sampling for this case study was completed by AgTech Solutions. Samples were collected on-the-go and bagged then taken back to a sampling facility to be pH tested in $CaCl_2$. The initial map identified 69.5 ha's of land with a pH ($CaCl_2$) less than 5.4 in the 0-10 cm fraction, with 25.2 ha's where pH was significantly yield limiting (pH of 4.4 and less).

Below are a series of map layers used throughout the process of this case study.

Initial mapping 2015



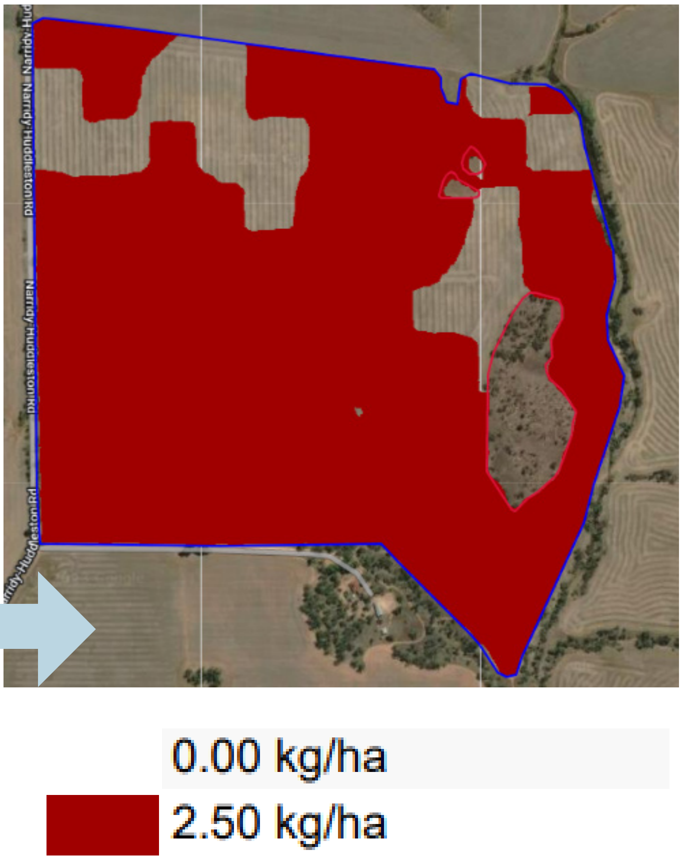


Figure 4. A variable rate (VR) lime requirement map, produced using the above (fig. 3) pH results and spread prior to sowing the 2016 crop.

Figure 3. pH ($CaCl_2$) taken on the top 0-10 cm's of soil in June 2015, prior to any application of lime. The lowest pH value was 3.6, with the highest pH value 7.1, equating to an average pH across the paddock of 5.0.

A variable rate lime application map was created using the above pH map (fig. 3) with areas below a pH of 6 ($CaCl_2$) spread with 3 t/ha of 90% EVN lime.

Follow up mapping 2018

The paddock was then pH mapped again at the start of 2018, two seasons post initial lime application. This was able to identify areas of the paddock that were still below the desired pH.

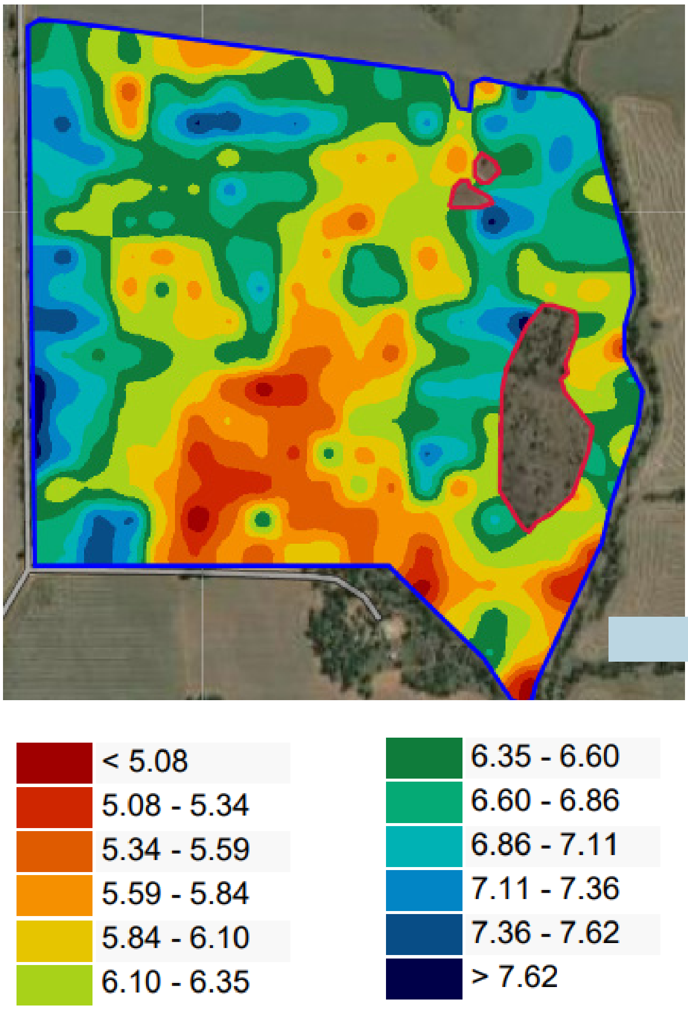


Figure 6. VR lime requirement map, produced using the updated pH map collected in 2018 (fig. 5), two seasons following the initial lime application. This map targets the remaining areas of the paddock with a pH value below 5 (CaCl2).

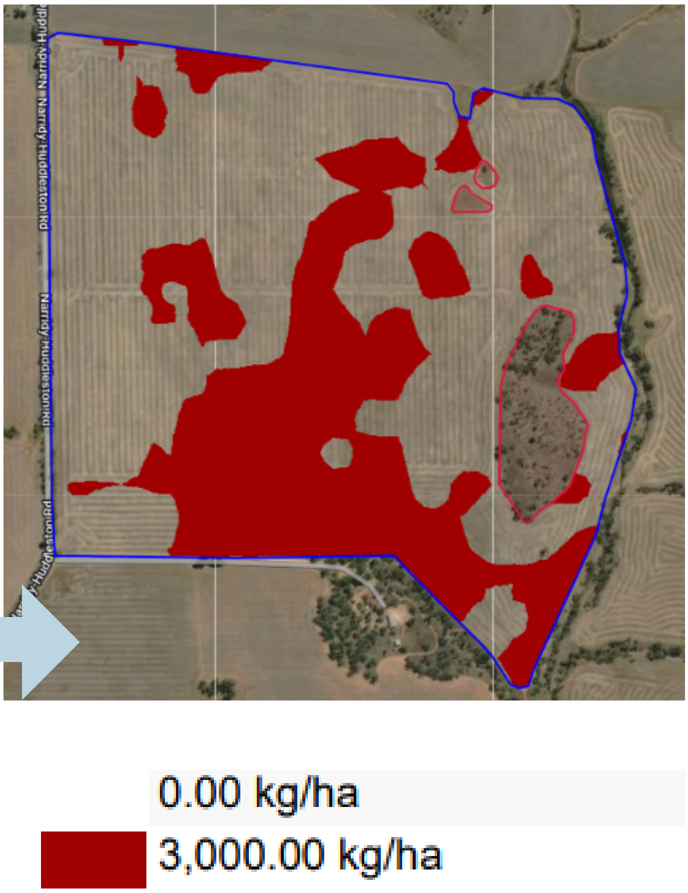


Figure 5. pH (CaCl2) taken on the top 0-10 cm's of soil in February 2018, two seasons after the initial application of lime.

The lowest pH value identified in the above pH map (fig. 5) collected in 2018 was 4.6, 1 pH unit higher than the original map collected in 2015. This shows that the lime application from 2016 improved soil pH between the application in 2016 and the pH map which was collected at the start of 2018.
Another lime requirement map was produced, using the updated pH map (fig. 5) to raise the remaining areas of the paddock below the desired pH of 5 (CaCl2), using lime with a 51% ENV.

Follow up mapping 2021

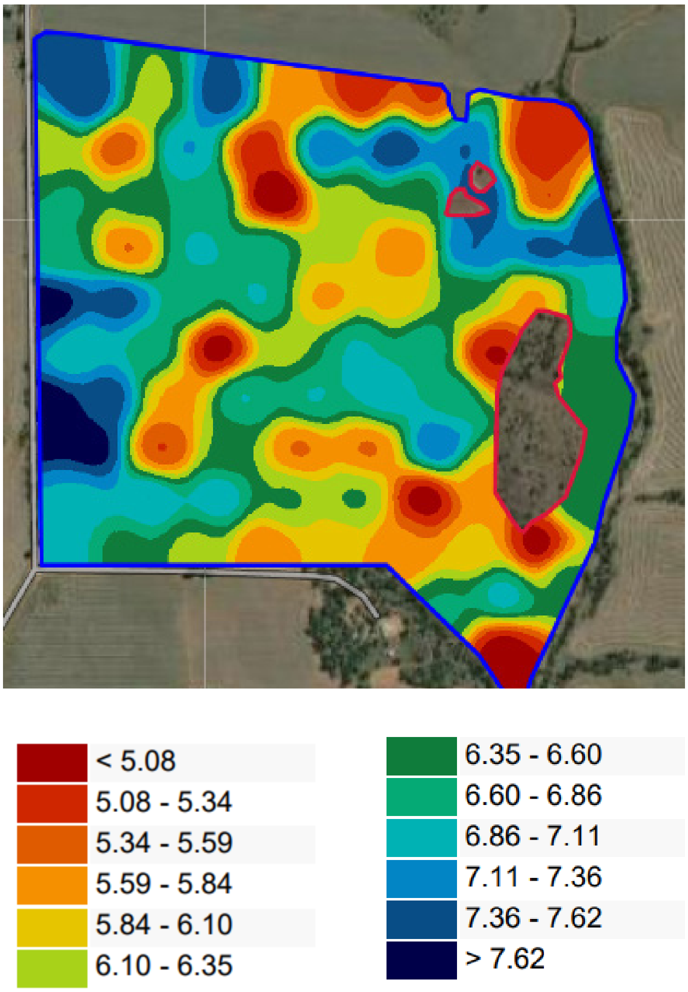


Figure 7. pH (CaCl2) taken on the top 0-10 cm's of soil in January 2021, six seasons after the initial application of lime and two season following the second application of lime.

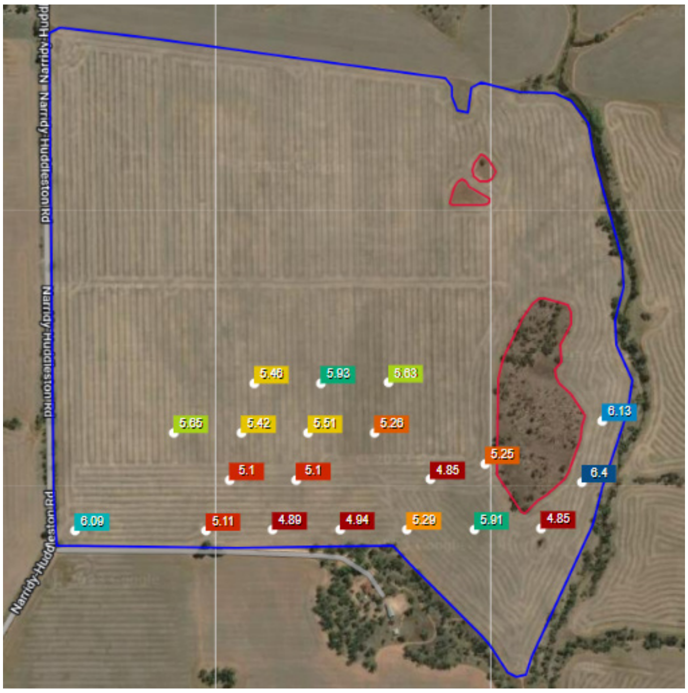


Figure 8. Strategic 10-20 cm samples were collected in December 2021, targeting the acid areas of the paddock to check for an acid band beyond the original sampling depth. These areas showed a top soil pH (CaCl2) ranging from 6.0 to 5.0. Sample points in yellow show further lime requirement to correct 10-20 cm acidity.

The minimum pH found from sampling in 2021 was 4.9, 0.4 units above the testing in 2018 and 1.4 units above the original sampling in 2015. Only 0.78 ha of the paddock showed a pH between 4.5 to 4.9, with majority of the paddock ranging in top soil pH from 5 to 7.4.
Rye grass patches were still being observed in 2021, hinting that there was still a pH imbalance in the bottom half of the paddock. Therefore, strategic deep sampling (10-20 cm) was completed at the end of 2021.

CONCLUSIONS

Soil acidification across our farming landscape is going to require an on-going management strategy to avoid yield loss. Modern farming systems are causing declines in pH in non-buffered soils because of inputs and cation removal with high production levels. Furthermore, pH stratification, due to the low solubility of our lime sources in combination with low to medium rainfall across our region should be considered when soil sampling and calculating lime requirement. As such, a strategy of soil pH monitoring that identifies zones for sampling from available data layers (yield, satellite imagery etc) and implementing a regular program (5-10 years depending on the production system) of soil sampling (0-5, 5-10, 10-20) will provide accurate data to determine required lime applications to manage and prevent yield limiting pH's from developing.

Another important consideration of soil pH amelioration is lime type, ensuring you match lime source to the job at hand. Seabed lime is the most soluble lime type, but typically has a lower neutralising value (NV) compared to rock lime. Rock lime is slightly less soluble, however if ground to a small particle size can have a high NV. Lime sand and dolomite are the least soluble sources. However, if you require increased magnesium then dolomite may be suited to your situation.

Soil pH mapping in combination with variable rate lime applications is well suited to many of the predominant soil types and production systems in the Upper North Agricultural Zone of SA. It enables growers to concentrate lime resources to the acidic areas of the paddock, avoiding alkaline areas resulting in improved overall paddock profitability for reduced inputs and at a reduced cost.

Report prepared for Upper North Farming Systems group by Beth Humphris, Elders Jamestown in 2022.

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References

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