Office Use Only	
Project Code	
Project Type	

FINAL REPORT 2022

Applicants must read the *SAGIT Project Funding Guidelines* prior to completing this form. These guidelines can be downloaded from www.sagit.com.au

Final reports must be submitted by email to admin@sagit.com.au as a Microsoft Word document in the format shown **within two months** after the completion of the Project Term.

PROJECT CODE	PA121
PROJECT TITLE	(10 words maximum)
A practical approach to sub-surface acidity in the Mid North	

PROJECT DURATION *These dates **must** be the same as those stated in the Funding Agreement.*	
Project start date	**1/07/2021**
Project end date	**15/12/2022**

PROJECT SUPERVISOR CONTACT DETAILS *(responsible for the overall project)*		
Title:	**First Name:**	**Surname:**
Mr	Adam	Brinkmann
Organisation:	**Precision Agriculture Pty Ltd**	

PROJECT REPORT: *Please provide a clear description for each of the following:*

Executive Summary (200 words maximum)

A few paragraphs covering what was discovered, written in a manner that is easily understood and relevant to SA growers. A number of key dot points should be included which can be used in SAGIT communication programs.

146 strategic soil sampling locations were selected across the MNHRZ region, and incremental 5 cm segmented soil samples collected to 20 cm depth. Sub-surface acidity was observed in all the project paddocks, to a greater or lesser extent. 69% of locations had increased subsurface acidity at 5-15 cm depth compared to the surface 0-5 cm layer, with a reduction in pH from 0-5 cm to 5-10 cm depth sometimes exceeding 1 pH unit, and in a few instances nearly 2 pH units.

Soil pH (0-10 cm) and EM38 were poorly correlated to sub-surface acidity, probably due to the influence of long-term management history including lime applications and productivity as well as the depth over which EM38 is measured. However, 0-10 cm CEC was a good predictor, with correlation $r^2 > 0.8$ in 16 out of 18 paddocks in relation to the strategic point location samples.

- Subsurface acidity was present between 5-15 cm depth where CEC in the top 10 cm of soil was less than 20 cmol(+)/kg, but absent when CEC exceeded this value.
- Even where there has been a history of liming, if the 0-10 cm soil pH is below 5.6, it is quite likely that pH stratification will be present.

Project objectives

A concise statement of the aims of the project in outcome terms should be provided.

The primary objective of this project was to increase the capacity of producers and advisors in the Mid North region of South Australia to cost-effectively measure, target and manage sub-surface acidity and acid throttles. It addressed three core research questions:

1. Subsoil pH variability and distribution through the profile – does it correlate with topsoil pH maps?
2. Value of proxy layers to direct subsoil sampling – can we use alternative soil data layers (e.g. Electrical Conductivity/elevation/radiometrics etc.) to more accurately target strategic subsoil sampling and amelioration?
3. Effectiveness of historic lime applications in ameliorating soil acidity throughout the profile?

Overall Performance

A concise statement indicating the extent to which the project objectives were achieved, a list of personnel who participated in the Research Project including co-operators, and any difficulties encountered and the reasons for these difficulties.

This project was led by Dr Murray Hart, Dr Kirsten Barlow and Mr Adam Brinkman from Precision Agriculture. The project was run in collaboration with Mr Jarred Tilley and the Mid North High Rainfall Zone Grower Group who organised the field days and workshops, as well as helping to identify project particpants.

Farmer collaborators in the project were: Craig Jaeschke, Jack Hanbury, Dane Sommerville, Jim Maitland, Angus Stockman, Richard Sandow, Kym I'Anson, Ben Plueckhahn, Ben Marshman, Frank McInerney, Sam Prizabella, Mick Faulkner, and Andrew Bruce. We would like to thank them for their support of this research.

The project delivered on all of its milestones and deliverables and was able to provide insights on the key objectives. The only outstanding component of the project is the conference paper which will be submit to the National Soils Conference in 2023, with the call for papers due to open early December 2022.

KEY PERFORMANCE INDICATORS (KPI) *Please indicate whether KPIs were achieved. The KPIs **must** be the same as those stated in the Application for Funding and a brief explanation provided as to how they were achieved or why they were not achieved.*		
KPI	**Achieved**	**If not achieved, please state reason.**
Presentation at MNHRZ spring field day and initial press release	Yes ☒ No ☐	
18 target paddocks identified, and existing data collated	Yes ☒ No ☐	
In-paddock data collection (soil sampling, EM38) complete	Yes ☒ No ☐	
• Final results presentation at MNHRZ autumn field day • Practical soil acidity workshop conducted • Case studies developed and published	Yes ☒ No ☐	
Conference paper developed and submitted and final press release	Yes ☐ No ☒	Conference paper has been completed, and will be submitted to the National Soils Conference in June 2023. The call for papers will open in December 2022.
Final report submitted	Yes ☒ No ☐	
	Yes ☐ No ☐	
	Yes ☐ No ☐	

TECHNICAL INFORMATION (Not to exceed **three** pages)

Provide sufficient data and short clear statements of outcomes.

Eighteen paddocks across the Mid North High Rainfall Zone (MNHRZ) from near Stockport in the south to Booborowie in the north were selected for sampling. There were three categories for paddock selection: (1) previously un-mapped with no recent liming history; (2) recently pH-mapped paddocks, preferably un-limed, but if liming had occurred it was no more than 12 months prior to sampling; and (3) previously pH-mapped and limed paddocks, where liming took place 3 or more years prior to sampling. Data collected from group 1 and 2 will indicate the extent, distribution, and variability of acid soils at depth without amelioration, allow for statistical analysis of the degree of correlation between topsoil and subsoil pH maps, and assessment of the value of potential proxy layers such as ECa and topsoil CEC to enable more cost-efficient subsoil pH sampling and management. Group 3 will identify the impact of topsoil amelioration on addressing lateral and vertical variability.

The previously un-mapped paddocks (group 1) were sampled on a 2-ha grid at 0-10 cm depth with samples collected in a transect across each grid. In addition, 5 grid squares were selected for segmented sampling with soil sampled at 0-5, 5-10, 10-15, 15-20 cm depths at the centre of the selected grids. The previously pH-mapped paddocks (group 2 & 3) were strategically soil sampled in 5 cm segments as above at 9 points based on existing topsoil pH mapping data combined with apparent Electrical Conductivity (ECa; via EM38) and elevation measurements. Areas where previous mapping indicated surface pH was ≥ 7.0 were avoided. All soil samples were analysed for soil pH, exchangeable cations (Ca, Mg, K. Na) and Cation Exchange Capacity (CEC) at a NATA-accredited laboratory.

Supporting data layers were also collected. All paddocks were surveyed with an EM38 sensor in vertical mode with a 25 m swath, with ECa maps created for each paddock. Average ECa and Radiometrics (Geoscience Australia, 2019) were also determined at each of the segmented soil sampling locations using a 5 m and 100 m radius buffer, respectively.

Soil pH varied significantly within paddocks and with depth down the soil profile (Figure 1). Across all paddocks, the average 0-5 cm pH_{Ca} was 5.71, with an overall range of 4.4 to 7.6, and individual paddock averages ranging from 4.77 to 6.70 (Figure 2). Substantial pH stratification and subsurface acidity (pH<5.0) was observed at many site locations. All paddocks had at least some areas where significant pH stratification was observed with 16 of the 18 paddocks having lower average and minimum pH in the 5-10 cm depths compared to the 0-5 cm. The range (minimum to maximum) of pH values was greater in the 5-10cm depth compared to the surface 5 cm in 14 of the 18 paddocks.

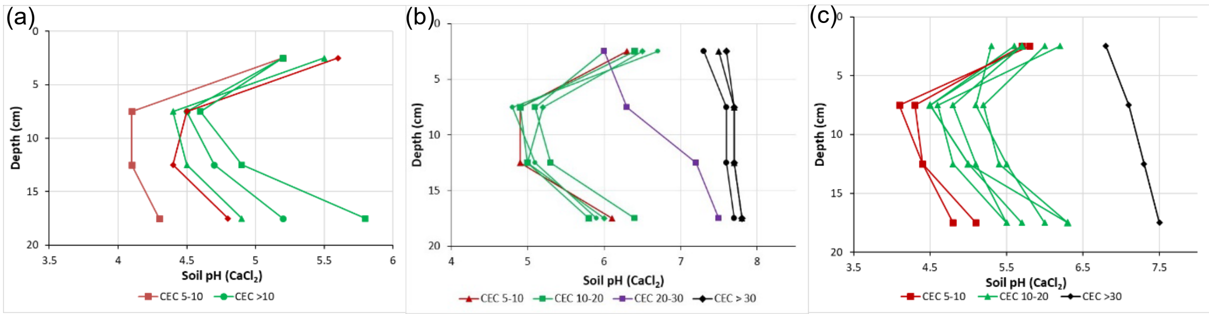

Figure 1. Example soil pH profiles to 20cm depth for strategic locations from paddocks categorised as (a) unmapped, unlimed; (b) mapped, unlimed/<12 mths; and (c) mapped, limed.

Out of the 146 sample locations, 101, or about 69%, had increased subsurface acidity at 5-15 cm depth compared to the surface 0-5 cm layer (defined as a decrease in pH of ≥0.2 units). Forty-five locations (31% of the total) lacked stratified subsurface acidity or were above pH 7.0. Of the 134 locations with surface pH<7.0, the median change in pH was -0.4 pH units between 0-5 and 5-10cm layers. Subsurface acidity peaked at 5-10cm depth in 80% of locations where it was present to at least some degree, and at 10-15cm depth in 17% of locations, with the remainder (3 locations) at 15-20cm depth.

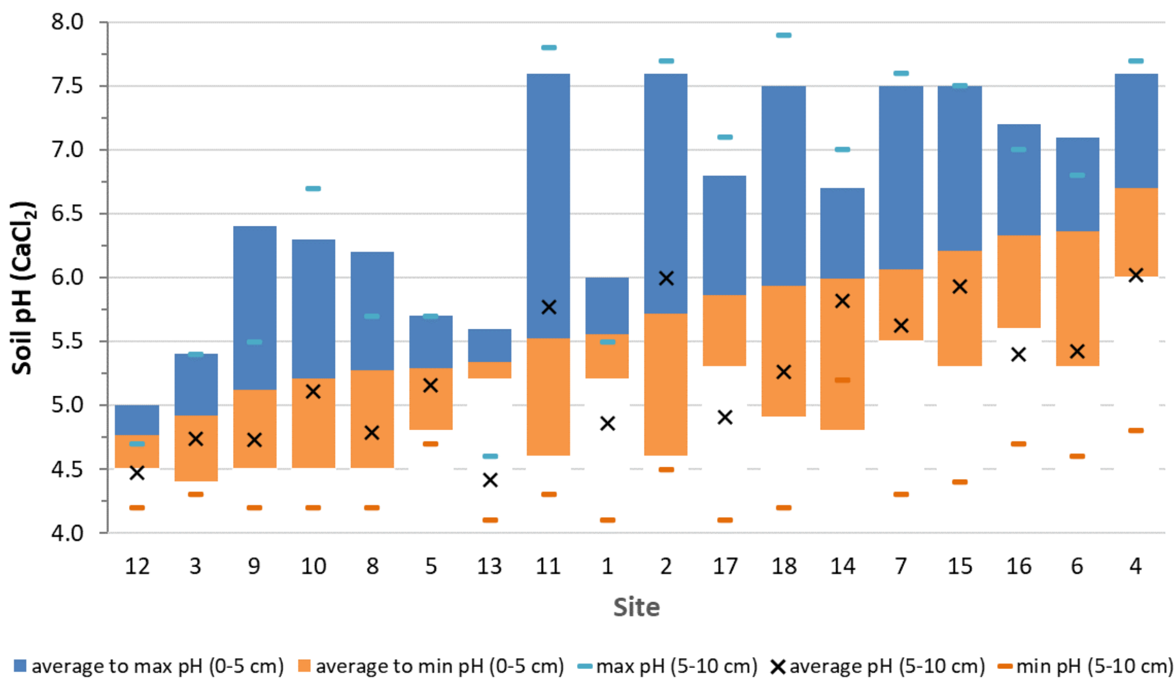

Figure 2: 0-5 cm (bars) and 5-10 cm (symbols) strategic point location soil pH results for each paddock, ranked from lowest to highest average pH for 0-5cm, and then in the same site order for 5-10 cm.

Although not large, there were some differing trends apparent between the three site categories when the surface layers were compared (Figure 3). The overall mean soil pH_{Ca} was lowest at 0-5 cm depth in group 1 (5.4), compared to group 2 (5.6) and group 3 (6.0). However, the mean drop in soil pH from the 0-5 cm to the 5-10 cm layer was smallest in group 1 (0.2 units) compared to groups 2 and 3 (0.35 and 0.63 units, respectively). If those sample locations where the surface pH was ≥ 6.0 are excluded, i.e., we focus on acidic soils only, then the average drop in pH from 0-5 cm depth to 5-10 cm depth is about 4 times greater in group 3 sites than that of group 1, and about double that of group 2. This shows the influence of the liming history of these sites but indicates that this lime had not worked into the soil profile deeper than just a few centimetres.

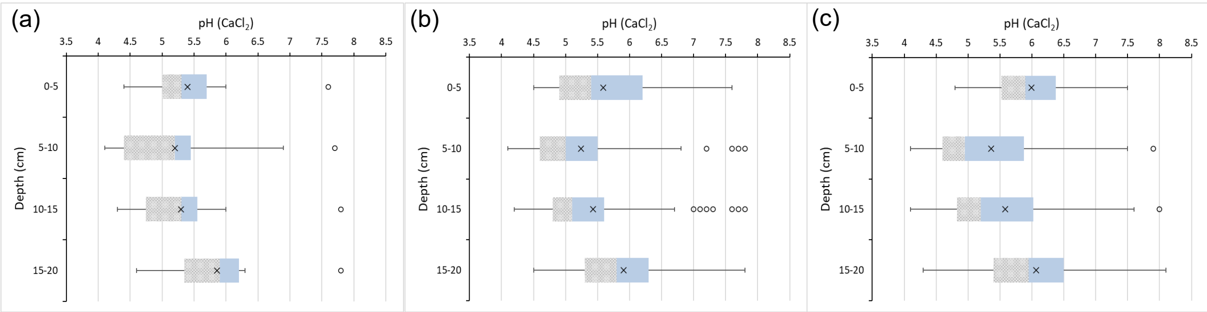

Figure 3. Box and whisker plots for all strategic segmented sampling results (0-5 cm, 5-10 cm, 10-15 cm, 15-20 cm) for (a) unmapped, unlimed; (b) mapped, unlimed/<12 mths; and (c) mapped, limed, categories. Boxed areas represent the middle 50% of data (interquartile range), crosses denote mean values. Dots are outliers beyond 1.5x IQR.

Neither EM38 nor radiometric gamma radiation were good predictors of the presence of subsurface acidity. However, 0-10 cm CEC was a good predictor, with correlation > 0.8 in 16 out of 18 paddocks in relation to the strategic point location samples. Regression of CEC against soil pH of the whole dataset was best described by a polynomial equation, and whilst there was a lot of variation, the overall relationship was reasonably strong (r^2 = 0.72), and highly statistically significant (p < 0.001).

The effect of CEC may be best observed when soil pH with depth is plotted against CEC category ranges across the whole dataset. A very clear pattern emerges, where subsurface acidity is present between 5-15 cm depth where CEC in the top 10 cm of soil is less than 20 cmol(+)/kg, but absent when CEC exceeds this value (Figure 4).

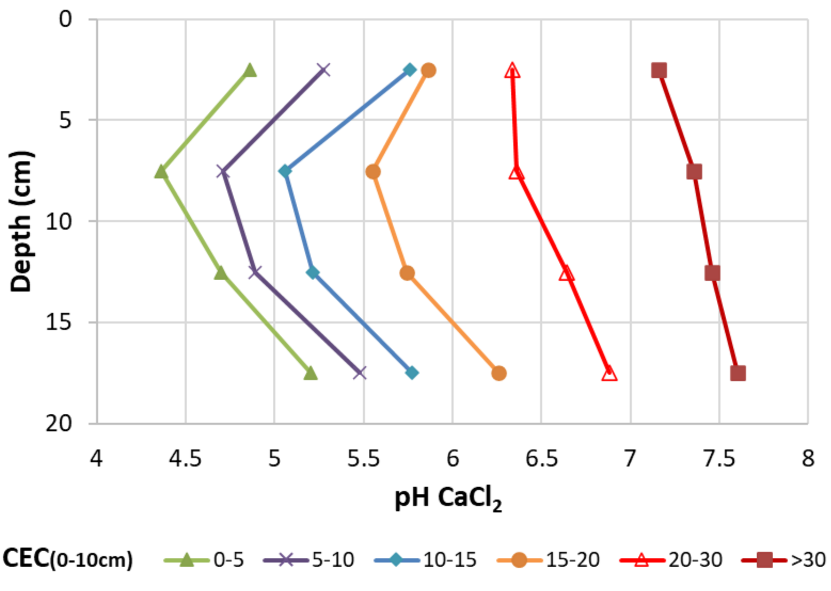

Figure 4. Soil pH with depth across all sites averaged across soil CEC class (0-10 cm).

These results are consistent with previous research and observations and are consistent with the relationship between a soil's pH buffering capacity and CEC. The results from this project indicate that even where there has been a history of liming, if the 0-10 cm soil pH is below about 5.6, it is quite likely that pH stratification is present.

CONCLUSIONS REACHED &/OR DISCOVERIES MADE (Not to exceed one page)

Please provide concise statement of any conclusions reached &/or discoveries made.

Sub-surface acidity was observed in all the project paddocks, to a greater or lesser extent. Soil pH (0-10 cm) and EM38 were poorly correlated to sub-surface acidity and did not provide a robust approach to the identification of areas at risk for targeted segmented sampling. We consider this to be due to the influence of surface lime additions and management history affecting the average 0-10cm soil pH, while EM38 readings are averaged over 0-1.5 m depth, which means they do not necessarily reflect the variation in surface soil properties. Soil 0-10 cm CEC measurements were well correlated to pH in 5-10 and 10-15 cm layers in all soil types. This is consistent with previous research and observations and is consistent with the relationship between a soil's pH buffering capacity and CEC. The results from this project indicate that even where there has been a history of liming, if the 0-10 cm soil pH is below about 5.6, it is quite likely that pH stratification is present. In such situations, we would recommend the use of strategic stratified soil sampling in 5cm increments to measure soil pH in more detail, to determine if and to what extent subsurface acidity may be present. Liming strategies will need to be adjusted accordingly compared to what might be calculated from standard 0-10 cm sampling. Conversely, where soil CEC in the 0-10 cm layer is greater than about 20 cmol(+)/kg, subsurface acidity is unlikely to be present.

INTELLECTUAL PROPERTY

Please provide concise statement of any intellectual property generated and potential for commercialisation.

n/a

APPLICATION / COMMUNICATION OF RESULTS

A concise statement describing activities undertaken to communicate the results of the project to the grains industry. This should include:

- *Main findings of the project in a dot point form suitable for use in communications to farmers;*
- *A statement of potential industry impact*
- *Publications and extension articles delivered as part of the project; and,*
- *Suggested path to market for the results including barriers to adoption.*

Note that SAGIT may directly extend information from Final reports to growers. If applicable, attach a list of published material.

The results were presented at two MNHRZ workshops held in Riverton, SA, on March 23rd and on July 22nd, 2022, with approximately 35 and 25 attendees, respectively.

Two Case studies were prepared highlighting results from paddocks with a history of liming yet still with significant subsurface acidity present. These have been circulated through:

- PA newsletters to approximately 1200 growers (check with Ebony)
- Sent to the MNHRZ group with approximately 80 members, and a wider circulation list of 287 contacts
- Available through PA website (Case Studies – Precision Agriculture)

One Conference paper will be submitted for presentation at the National Soils Conference to be held in Darwin in June 2023

POSSIBLE FUTURE WORK

Provide possible future directions for the research arising from the project including potential for further work and partnerships.

Having found significant variation in soil acidity laterally across paddocks as well as with soil depth, growers in the MNHRZ group are interested in investigating spatial variation in available soil phosphorus across paddocks. This ties in quite closely with project PA121, since soil pH has a strong influence on the availability of soil P.

The results from project PA121 have demonstrated the presence of a significant amount of hitherto unknown subsurface acidity in almost all the paddocks sampled, and the conclusions we can derive from the project are quite clear. However, it is comprised of a small dataset, and extrapolation to other areas in South Australia can only be done with caution. The 2017 DEWNR Soil and Land Program has identified large areas in other parts of South Australia that are at high risk of increasing soil acidification e.g. Eyre Peninsula, Hills and Fleurieu Peninsula, Limestone Coast. Conducting a similar project to PA121 in another part of the state would provide greater confidence in the results and conclusions from this project and if similar results are found would highlight the potential need for greater lime application rates than was previously thought necessary.

Producers in medium to low rainfall areas are keen to understand the potential for variable rate management of soil ameliorants and nutrients. Grid soil sampling isn't always economical in these regions and instead soil management zones with strategic soil sampling to validate the zones is required. However, they aren't confident on the best approach to use as there are a lot of options discussed in the marketplace, from yield and protein data, EM38, NDVI as well as other remote-sensed data. While all of these layers can provide invaluable insights into paddock scale variation, the question arises, which provides the best insights into surface and sub-surface soil constraints? A project using a grid sampling approach to collect baseline data, combined with different approaches to the development zones would provide detailed insights into different zoning approaches and how these correlate to soil parameters, as well as the level of variation that is not accounted for.

Potassium management is a key consideration for producers across SA, particularly farming systems which have a hay crop within their production systems. While there has been significant research around critical potassium levels, producers are still seeing potassium responsiveness in their farming systems. A project investigating spatial potassium variability within paddocks and down through the soil profile, and how this is impacting on potassium availability, would provide farmers with information to improve nutrient use efficiency and reduce input costs without compromising on yield.