Quantifying benefits of pH mapping technology and variable rate liming versus blanket rate approaches

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Abstract

Soil acidity is a soil condition where there are excess hydrogen ions present due to the removal of alkaline nutrients in plant and animal products; addition and leaching of nitrogen from fertilisers and legumes and the build-up of organic matter. Soil pH($CaCl_2$) levels of 5.2 to 8.0 provide optimum conditions for most agricultural plants. All agricultural plants are affected by the extremes of pH, however different plant species have significant variation in their acidity and alkalinity tolerance. Lime (calcium carbonate) and other liming materials (dolomite, lime sand) reduce soil acidity via neutralising the acid reaction within the soil. Traditionally lime has been applied at standard blanket rates of between 1 – 2.5 t/ha. Grid soil pH mapping enables measurement of spatial pH variation within a paddock. Analysis of over 19,000 ha of mapping in Victoria has demonstrated that 33% of this area would not receive an optimum lime rate (outside of 1 -2.5 t/ha) for a target pH($CaCl_2$) 5.2 scenario. Ten percent of this area required more lime than 2.5 t/ha to achieve the target pH level while 23% did not require any lime.

Keywords

Acidity, pH, lime, mapping.

Introduction

Soil acidity is a soil condition where there are excess hydrogen ions present due to the removal of alkaline nutrients in plant and animal products (Taiz and Zeiger 2010); addition and leaching of nitrogen from fertilisers and legumes and the build-up of organic matter (Barson 2013; Taiz and Zeiger 2010). Soil pH($CaCl_2$) levels of 5.2 to 8.0 provide optimum conditions for most agricultural plants. All agricultural plants are affected by the extremes of pH, however different plant species have significant variation in their acidity and alkalinity tolerance. Lime (calcium carbonate) and other liming materials (dolomite, lime sand) reduce soil acidity via neutralising the acid reaction within the soil.

Soils in most parts of Victoria are generally acidic. These acid soil conditions are known to limit plant production in agricultural industries (Agriculture Victoria 2017). Optimum soil management for any purpose requires that soil pH is adjusted to a desirable pH range (Sims 1996), generally 5.2 or 5.5 pH($CaCl_2$) for Victorian soils. The lime requirement of a soil is the quantity of lime required to neutralise acidity to obtain the desired pH range for optimal crop growth (Godseyn et al. 2007; Mclean 1982). As agricultural practices increase acidification rates, it is of growing concern that traditional blanket rate lime applications may no longer be enough to address acidification (Miller 2015). A more accurate determination of soil pH across a paddock is needed to determine the lime requirements of a soil so resources are not wasted applying lime to areas where it is not required (Stock Journal 2015).

Methods

A grid soil mapping process began with two-hectare sampling grids being designed using Geographical Information System (GIS) software for each paddock. Care was taken in designing the sampling plan and whilst sampling in the field, to avoid sampling in or in close proximity to, vegetation areas, swampy or wet ground, fence lines (both existing and removed), headlands, and highly trafficked areas. Sampling in or near these areas can distort the accuracy of the data acquired. Grid soil mapping is non-random, overcoming landscape variation and enables sub-paddock variation to be accurately identified. Each sampling location was given a unique GPS location and identification (ID) number (Figure 1).

Following the production of the sampling plan, grid sampling was conducted using a combination of Amity™ or Wintex™ hydraulic soil samplers. This largely occurred between November 2016-March 2017. All sampling was 0-10 cm depth. Eight 0-10 cm soil cores were collected along a 100 m transect, running on a 45-degree angle over each 2 ha region. These eight cores were combined in a sample bag with a matching

ID to the sample plan ID and sealed. This was repeated for every sampling location within a paddock. The core sampler bucket was ensured to be clear of soil between each sampling location to eliminate contamination between samples.

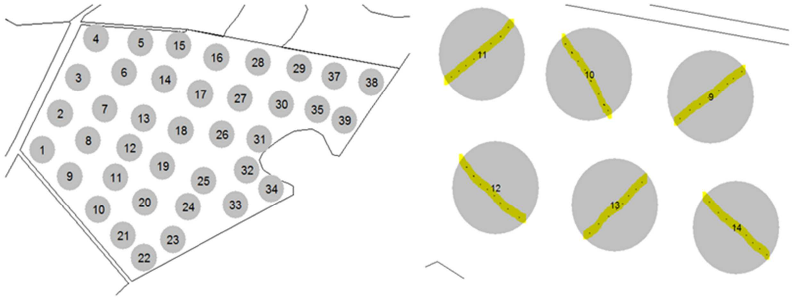

Figure 1. Example sampling plan. Each sampling location is represented with a 100 m diameter circle and numbered for identification, as seen on the left-hand image. Eight samples are taken along a 100 m transect on a diagonal across the 2 ha sampling location, as marked in yellow in the right-hand side of Figure 1.

The collected soil was sent to APAL laboratories, Adelaide, for soil pH($CaCl_2$) analysis. Strategic soil textural analysis was also completed on nominated samples, approximately every 20th sample or where textural variation was observed in the field. Textural analysis was done to account for the effect of soil texture on the pH buffering capacity in the lime rate calculations. Soil pH($CaCl_2$) analysis is favoured over pH(H_2O) as it is not susceptible to seasonal and climatic variation. The soil pH(CaCl2) results from the laboratory were digitally mapped utilising the same GIS software as to produce the sampling plans, where contouring allows pH trends across the paddock to be seen (Figure 2). From this, the lime requirement (t/ha) for each paddock is calculated by the following equation:

Lime Requirement (t/ha) = ((Target pH – Current pH) *Soil Texture Factor)/Lime Neutralising Value (Rural Solutions SA 2011).

The target pH($CaCl_2$), either 5.2 or 5.5, was as desired by the individual farmer, the soil texture factor is attributed by the texture class of the paddock being mapped, and the lime neutralising value is determined by laboratory analysis of a lime source, and is a measure of the ability of the lime to neutralise soil acidity (White 2006). The setting of 5.2 or 5.5 as common pH targets is due to the majority of broadacre crop species having an optimum pH range between 5-7pH($CaCl_2$) (Hazelton and Murphy 2007), and that ameliorating soil pH($CaCl_2$) to 5.2 will amend many of the problems associated with soil acidity (Fenton 2003), such as the slow turnover of organic matter and poor root nodulation (White 2006).

Applying the above formula to the pH map allows a variable rate lime application map to be produced (Figure 2). This provides the total lime requirement for a paddock and details where different rates of lime are required. This application map is converted to a digital file for variable rate capable spreader controllers to enable automated variable rate spreading. Alternatively, this map can be uploaded to certain GPS screens to enable manual variable rate applications to occur.

Results and Discussion

During November 2016 – March 2017, 19,035 hectares were mapped for soil pH across Victoria. From the results obtained it was observed that 77% of the soil mapped was below optimal pH levels for agricultural use (Table 1). Furthermore, the average pH ($CaCl_2$) of all the soil tested was 4.9 and average soil texture measured was a sandy loam.

Table 1. Soil pH ranges across Victoria (November 2016-March 2017). The majority (48%) of soil mapped was found to have a pH($CaCl_2$) of 4.8-5.1, with 77% of the soil tested having a pH($CaCl_2$) below 5.2.

pH(CaCl2)	Percentage
5.8+	1%
5.2-5.7	22%
4.8-5.1	46%
4.5-4.7	26%
<4.4	5%

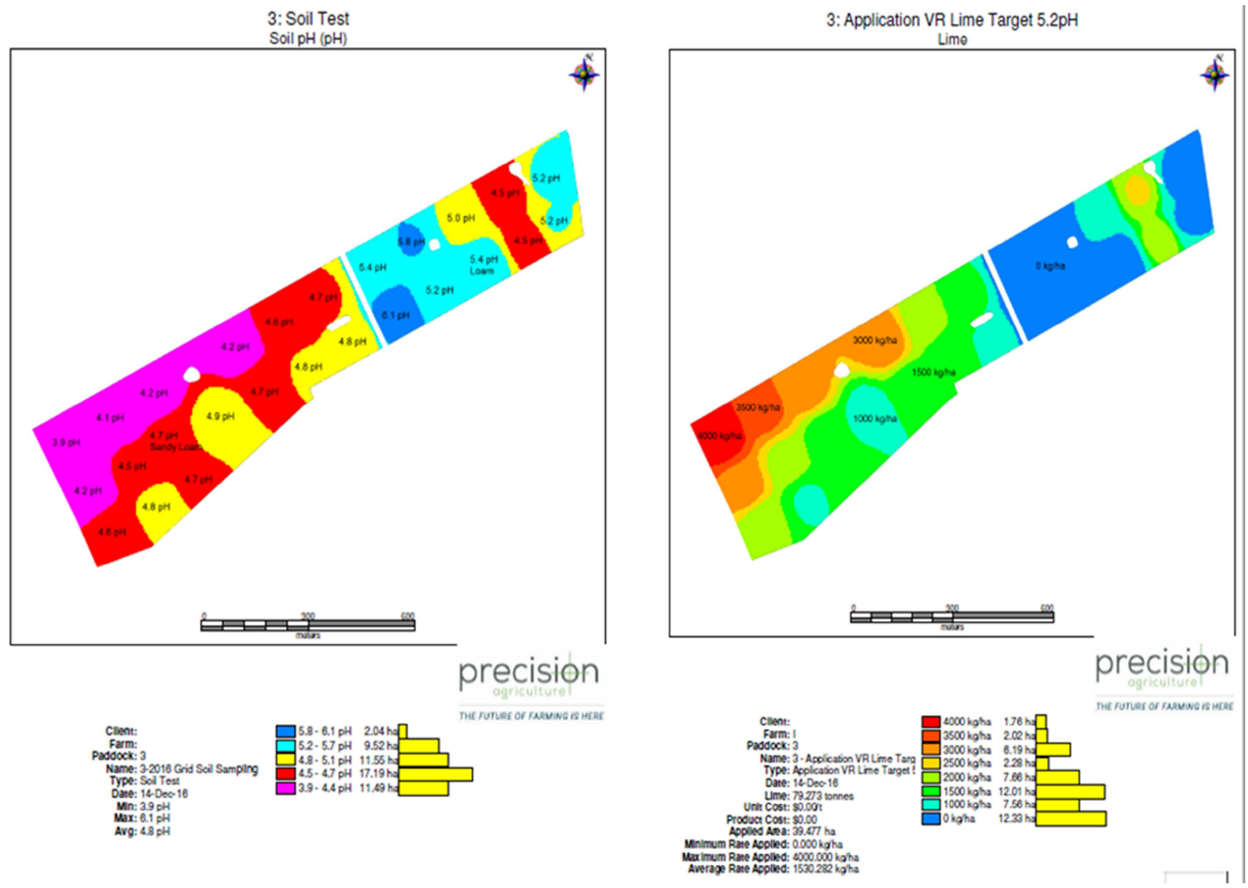

Figure 2. Soil pH and variable rate lime application maps. On the left-hand side is the pH map produced from the laboratory soil pH results. Each sampling point is labelled with the pH at that location. On the right-hand side is the variable rate lime application map, displaying the lime requirements across the paddock as determined from the soil pH map. Note the visible variation in lime requirements across the paddock, with red and orange areas having the highest lime requirements, through to the blue zones, which require no lime.

It was also observed that in the target pH($CaCl_2$) 5.2 mapping scenario, 10% of land was not receiving the lime it required, therefore requiring greater liming rates than the 2.5 t/ha applied in some traditional blanket rate applications in Victoria (Table 2). While 67% of the area mapped required 1-2.5 t/ha of lime, and this requirement would be met by blanket applications, product would also be wasted, through applying more lime than necessary in some places, and insufficient amounts in others. In fact, 23% of the mapped area required no additional lime to be spread under the 5.2 pH($CaCl_2$) scenario. Based on a lime cost of $55/tonne (delivered and spread), the findings showed an average saving of $64.50/ha by utilising a variable rate lime application strategy compared to a blanket rate application of 2.5 t/ha. These financial savings enabled farmers who adopted grid soil mapping to receive, on average, a 4.5:1 return on investment (based on $14/ha mapping cost).

Table 2. Percentage of area mapped in Victoria with lime rates above 2.5 t/ha, between 1-2.5 t/ha and requiring no additional lime under both target pH($CaCl_2$) scenarios of 5.2 and 5.5.

Lime Requirement (t/ha)	pH($CaCl_2$) Target 5.2
Above 2.5t/ha	10%
1-2.5t/ha	67%
0t/ha	23%

The 5.5pH($CaCl_2$) target scenario saw a greater percentage of mapped land not receiving sufficient lime under a 2.5 t/ha blanket rate lime application strategy, with 21% of the area having a lime requirement above 2.5 t/ha. Despite the high pH target, the 5.5 pH($CaCl_2$) scenario still found that variable rate lime application based on grid soil mapping would see an average lime saving of 23% compared to a 2.5 t/ha blanket application of lime. This was in part due to 13% of the area mapped in Victoria not requiring any additional lime to be applied under this target pH($CaCl_2$) scenario. Again, based on a lime cost of $55/tonne (delivered

and spread), an average saving of $34.75/ha could be realised when compared to the required investment for a blanket rate application strategy of 2.5 t/ha. This resulted in, on average, 2.5:1 return on investment (based on the $14/ha mapping cost) for farmers who invested in grid soil mapping.

Conclusion

It is concluded when comparing a variable rate lime application strategy to a traditional blanket application, a significant area of land is receiving lime that is not necessary to reach the desired pH($CaCl_2$) targets. This is not only a waste of a resource that could be better utilised elsewhere in the paddock, where greater lime rates are required, it also increases the chance of over liming and damaging soil health.

Grid soil mapping enables sub paddock pH($CaCl_2$) variation that is ignored in randomised whole paddock soil testing to be visualised and managed. These variations in soil pH may be due to factors including soil type, old paddock histories within expanded paddocks, swamps and previous vegetation. Grid soil mapping allows accurate, quantitative measurements to enhance soil fertility and productivity. The real gains to be made from grid mapping and variable rate lime application do not solely lie in financial savings made from reducing lime requirements. The more significant benefit from grid soil mapping and variable rate lime application is in better allocating resources. Under blanket rate applications many areas will never receive the high lime rates they require. Grid mapping allows these areas to be identified and lime that would have little effect elsewhere in the paddock is reallocated to maximum affect. This in turn unlocks the productive capabilities of these soils where pH is the key yield limiting factor.

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