Catchment based long-term monitoring reveals the value of lime application to correct soil acidity.

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Abstract

Continuing acidification of agricultural soils in Australia is recognised as a key limitation to sustainable crop and pasture production. Whilst not profiled to the same extent as salinity, soil acidity is the major national soil constraint affecting millions of hectares across Australia. Being able to effectively manage soil acidity requires an accurate assessment of the condition of the soil resource at all scales—from individual paddocks to the whole national situation. The National Land and Water Audit II has begun the process of developing protocols for monitoring soil acidification and acidity. In Western Australia, Precision SoilTech has developed a long term monitoring regime to address this requirement.

In this paper, we report on the Gabby Quoi Quoi (GQQ) a 22,000-hectare catchment located in the central agricultural region of WA. Growers in the GQQ catchment are particularly innovative and have a strong focus on managing their acidic soils. In 1999 approximately 300 geo-located soil profiles were collected from a range of soil types over the catchment. Samples were collected across the broad soil texture groups. In general, lower soil pH was more common in the sandier textured soils. Using GPS technology, all sites were sampled again in 2006. Changes in soil pH on the catchment scale, in relation to lime use were detected using this approach. Although lime was being used, the current rates are below those recommended to achieve and sustain the desired soil pH profile in the long-term.

Key Words

Soil acidity, lime application, regular soil testing

Introduction

Soil acidity is recognised as the ‘sleeping giant’ of the major soil degradation issues impacting on productive agriculture in Australia (NLWRA, 2001). Several major research development and extension campaigns between the 1990’s and 2002, particularly in WA, have demonstrated and promoted the benefits of using lime to increase soil pH (Gazey, 2002). Whilst lime use has increased markedly, there is a paucity of information to allow an accurate assessment of current trends in soil pH at the farm and state scales. To effectively manage the nation’s soil resources and improve agricultural production, farmers and the state and federal agencies require detailed information on managing acid soils.

Precision SoilTech, a WA based soil-testing company, provides a soil monitoring service to farmers in WA using patented technology which can collect soil samples quickly without contamination between layers. With seven extremely cooperative farmers in the GQQ catchment in the central WA wheatbelt, Precision SoilTech initiated a long-term trial in February 1999. Soil sampling was conducted in the 22,000-hectare catchment and included 7 individual farms; a total of 68 different paddocks (total area approximately 4,200 ha) from which 287 topsoil (0-10 cm) and 265 midsoil (10-20 cm) were sampled. All sample sites were geo-located using dGPS technology (accurate to 2m), and landscape position (hilltop through to valley floor) and soil type were recorded. At each sample location, 10 soil cores were collected (from a sample area approximately 4m by 8m) and bulked together. Using the initial soil pH measurements, and an estimate of buffering capacity, (from the soil texture) growers were provided with liming recommendations for a ten-year period that were aimed to increase topsoil pH to 5.5 and midsoil pH to around 4.8.

Between 1999 and 2006, the seven cooperating farmers within the GQQ catchment recorded in detail all crop yields, all fertiliser and ameliorant (lime, gypsum and dolomite) inputs over the seven years. In March 2006, all sites were resampled in the same manner as the initial 1999 sampling. The changes in both topsoil and midsoil pH under the various liming regimes are reported upon. All pH values referred to in this paper are measured in 1:5 soil:0.01M $CaCl_2$.

Results and Discussion

Soil texture and pH profiles

Sandy textured soils dominate the GQQ catchment. In 1999, most sites were sands (41%) followed by loams (20%) and sandy loams (18%). Fine textured clay and loamy clays (Table 1) were found at the least number of sites. The proportion of soils in the key soil groups, and the ranges in both topsoil pH (4.0–7.6) and midsoil pH (3.8–7.7) were similar and typical of soils in this region of the WA wheatbelt (McArthur, 1991). With the dominance of sandy textured soils, growers in the GQQ catchment have previously identified soil acidity as a constraint to their productivity (Edkins, 1998) and were keen to implement a liming regime (Lightfoot, 1999).

Table 1. Soil types and pH profiles for study sites in 1999 and 2006.

Soil type	% of sites (number)		pH range			
			Topsoil (0–10 cm)		Midsoil (10–20 cm)	
	0–10 cm	10–20 cm	1999	2006	1999	2006
Sand	41% (119)	45% (118)	4.0–7.5	4.2–6.7	3.8–7.7	4.1–6.0
Loam	20% (57)	20% (52)	4.0–5.7	4.1–6.8	3.9–6.6	4.3–5.8
Sandy loam	18% (52)	18% (48)	4.0–5.9	4.3–6.6	3.9–6.1	4.3–6.3
Loamy clay	11% (31)	9% (24)	4.1–5.7	4.2–6.5	3.9–5.9	4.3–6.4
Clay	5% (14)	4% (11)	4.2–5.5	4.4–5.6	4.0–6.1	4.9–5.8
Duplex	5% (14)	5% (12)	4.2–7.6	4.4–7.8	3.9–5.4	4.4–5.6
Total	287	265	4.0–7.6	4.1–7.8	3.8–7.7	4.1–6.4

In 1999, the topsoil pH for the GQQ catchment ranged between 4.0 and 7.6. Approximately 80% of the soils sampled from the catchment had a soil texture lighter than loam, and the majority of these soils had a pH under 5. After 7 years, when resampled in 2006, the topsoil pH for the GQQ catchment still ranged between 4.1 and 7.8. By 2006, the percentage of soils with a topsoil pH above 5.5 had increased from 5% up to 17% (Table 2). There were significant ($p<0.05$) pH increases observed within the other pH ranges as shown in Table 2.

In 1999, the midsoil pH ranged between 3.8 and 7.7. Changes in midsoil pH followed similar trends to topsoil pH, but surprisingly, larger changes were noted compared to the topsoils (Table 2). In 2006, the midsoil pH ranged between 4.1 and 6.4. Of note was the proportion of midsoils with a pH above 4.6, which increased from 37% to 76% during the study. Whilst this is an encouraging trend, care must be taken when interpreting such data. Although the initial project aim was to have the majority of midsoils with a pH above 4.8, using arbitrary pH categories to consider the situation on a catchment scale must be viewed with caution. Small changes in midsoil pH (e.g. from 4.5 to 4.6, which are within sampling variability) can lead to a shift between the arbitrary categories used to consider the pH data. However, given the relatively large number of samples involved (each consisting of 10 combined soil cores), the diversity of soil types and management imposed we are encouraged by the trends observed.

Table 2. Changes in distribution of sites in each pH category in 1999 and 2006.

Specified pH categories	**1999** % of total (*n*)		**2006** % of total (*n*)	
	Topsoil	Midsoil	Topsoil	Midsoil
<4.0	1 (2)	14 (37)	0 (0)	0 (0)
4.1–4.5	37 (107)	49 (130)	14 (39)	24 (57)
4.6–5.0	42 (122)	22 (59)	45 (130)	45 (104)
5.1–5.5	15 (42)	10 (27)	24 (70)	20 (46)
>5.5	5 (14)	5 (12)	17 (48)	11 (26)
Total	100 (287)	100 (265)	100 (287)	100 (233)

Recommended lime rates

Of the 68 individual paddocks studied, growers applied lime to 52 paddocks during the 7-year study, with the remaining 16 paddocks not treated. This degree of adoption of liming is greater than in other areas, and is likely to result from the interest of these particular growers, their recognition of acidity as a constraint to profitable agriculture, and their desire to rectify the problem. Although 73% of paddocks received a single application of lime with only 13% received two applications of lime (Table 3). Across the catchment, most lime was applied in 1999 (1680 t), with only 150 t applied in 2005 (Table 3).

Table 3. Percentage of paddocks limed, frequency of application and total applied in catchment

Year	% Limed (number)	% Limed once	% Limed twice	Amount of lime applied annually (t)
1999	37 (25)	35		1680

2000	15 (10)	52		530
2001	7 (5)	56		445
2002	7 (5)	61	3	490
2003	10 (7)	68	7	620
2004	9 (6)	71	11	320
2005	3 (2)	73	13	150

The proportion of growers following the recommended liming regimes declined as the recommended rate of lime increased. Lime application at 1 t/ha was the most common, irrespective of the recommended rate that was based upon the initial soil pH and the buffering capacity of the dominant soil type in the paddock. This finding was not surprising. Most growers have significant areas of acid soils on the properties they farm, and budgets to treat all acidity problems are usually not given the priority necessary to follow the recommendations. In addition, much of the Department of Agriculture and Food Western Australia and Aglime of Australia’s field based research on lime application in the WA wheatbelt conducted over the past 20 years, tended to use low rates of one to two tonnes of lime. Consequently, the general and widespread extension efforts have tended to promote lime use at 1 t/ha, especially in situations where topsoil acidity was the major limitation. However, Davies *et al.* (2006) recently showed that wheat yields on average increased by 12% when lime was applied at 2 t/ha, compared with a 6 to 8% increase when lime was applied at 1 t/ha. Although farmers understand the need for frequent lime application to counter acidification, lime use is less than required. Limitations to lime use may include the cost of freight, the long delays in visual responses and the fear of induced trace element deficiencies.

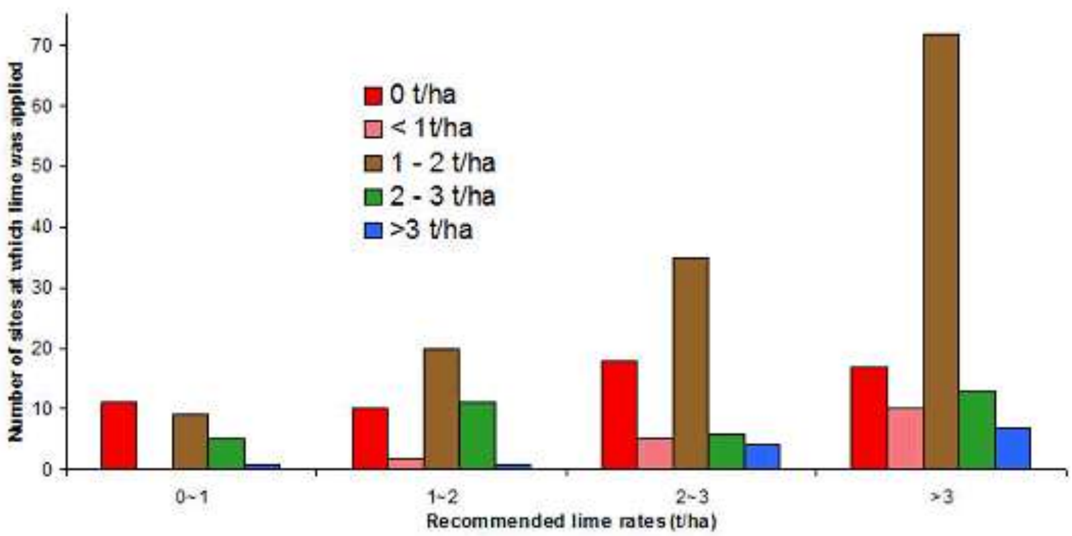

Figure 1. Lime rates suggested versus lime rate applied

Conclusions

We have demonstrated a unique and economically viable method of monitoring soil acidity. Using this technology, and sampling across a significant proportion of the whole catchment, enabled us to make realistic estimates of the potential gains from lime application. Assessment of the pH status of paddocks as we have done in this study also allows accurate 10-year liming recommendations to lift topsoil pH to 5.5, and midsoil pH to above 4.8, to be developed for the farmer at the paddock scale.

Encouraging trends have been observed in the soil pH measured within the GQQ catchment. Both topsoil and midsoil pH are trending towards long-term targets. However, despite the promising results, the quantity of lime that has been applied remains below that required to firstly ameliorate, and subsequently maintain soil pH in the optimal range.

Farmers are reluctant to apply high rates of lime. To achieve the required lime use targets, thereby lifting soil pH to the desired range and countering ongoing soil acidification will remain continuing challenges. The affordability of amelioration will decrease as the terms of trade continue to decline. A targeted extension campaign in needed to inform farmers, private agronomists and consultants, that an increase in the rate of lime application is necessary to achieve the long-term soil pH profile targets and associated gains in productivity.

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