Is Dealumination Limited to the Waikato Region of New Zealand, or is it Wider Spread?

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Abstract
Dealumination is a term used to describe an increase in the concentration of acid recoverable Al as a result of accelerated weathering or chemical attack of primary crystalline and short-range order aluminosilicates (Taylor & Kim. *In Press* Australian Journal of Soil Research 47 (8)). Briefly, this process has been observed in farmed soils but not in soils under background or forestry land uses. Two specific mechanisms that could favour Al mobilisation from clay surfaces include partial dissolution by local areas of high acidity associated with fertiliser granules, and surface complexation and extraction by the fluoride and residual hydrofluoric acid present in phosphate fertilisers.

The process of dealumination has been identified in farmed soils in the Waikato region. This study assesses if this process is occurring in two neighbouring regions, Auckland and the Bay of Plenty by comparing regional soil quality monitoring data from the three regions. As the sites used for regional soil quality sampling are resampled on a 5-6 year rotation, trend in data over time, including the speed of this process, were also estimated.

Key Words
Dealumination, accelerated weathering, aluminium, fluorine, fertiliser.

Introduction

Soil quality monitoring programs are carried out in the Auckland, Bay of Plenty and Waikato regions to assess soils for production and environmental protection. Monitoring in the Waikato region identified an increase in strong acid recoverable Al and associated elements in farmed soils compared to background soils. These results have been interpreted as the potentially interesting soil process, dealumination, as the mechanism for the observed increases (Taylor & Kim *In Press* Australian Journal of Soil Research 47 (8)). This paper shows Waikato region results for Al, and a cluster of elements associated with aluminosilicates, were unusual in the context of known sources. Given their high natural concentrations (above 2%), we did not expect any common external source to be able to cause a measurable increase in Fe or Al in farmed soils. In keeping with this, Fe showed no such evidence of a concentration increase in farmed soils. By contrast, farmed soils showed a significant ($p<0.0001$) concentration increase in acid-recoverable Al. This increase was remarkable, not so much for the size of the enrichment factor (1.5), but for the element involved and the amount of additional Al represented – an additional 13,700 mg/kg of acid-extractable Al in the farmed soils, at the time of publication.

Two specific mechanisms were presented that could favour Al mobilisation from clay surfaces including partial dissolution by local areas of high acidity (about pH 2) associated with phosphate fertiliser granules, and surface complexation and extraction by the fluoride and residual hydrofluoric acid present in phosphate fertilisers. New Zealand soils are regarded as being naturally low in P (McLaren & Cameron 1990) and require inputs of phosphate fertilisers for optimal production. A typical rate of application on a dairy farm in the Waikato region is about 400kg superphosphate/ha/y. Superphosphate fertiliser contains about 1-3% F.

To assess if this process is isolated to the Waikato region, or more widespread, data from the two neighbouring regions, Auckland and Bay of Plenty is compared with that from the Waikato region.

Methods

Soil quality monitoring
Soil quality monitoring sites were chosen to cover a representative range of soil types and land uses. Sampling consisted of 25 soil cores (0-100 mm) over a 50 m transect, which are combined to form composites for analysis (Sparling *et al*. 2002).

Sites were identified on the basis of their current land use and what is known of their land use history. There are far fewer not farmed sites than farmed land sites. They were all long-term forest, or wetlands, uninfluenced by anthropogenic activities for the life of the trees. Some of these sites may have been logged or cleared by early generations, but atmospheric inputs in New Zealand soils are relatively low, and for the most part these sites are regarded as being close enough to background to serve as a useful point of comparison. Farmed sites included pastoral cropping and horticultural land uses.

Samples are analysed for an established set of soil quality chemical and physical parameters following Sparling *et al*. (2002) and for 32 elements following EPA 200.2 (total recoverable metals hydrochloric/nitric acid digestion). Measurements were made at IANZ-accredited laboratories (soil quality chemistry at Landcare Research, Palmerston North, soil quality physical parameters at Landcare Research, Hamilton, and elemental analysis by ICP-MS at Hill Laboratories, Hamilton).

Statistics
Relative enrichment (or depletion) of Al in farmed soils was determined by calculating the ratio of the mean results from farmed soils with the mean from not farmed soils. Where necessary, data was transformed to form a normal distribution. Pooled Student's t-tests were used to assess significance of the difference between each pair of means. For the subset of samples from sites sampled twice, about 5 year apart, significance was assessed using paired Student's t-tests after data was transformed to a normal distribution.

Results

Consistent with the results from the Waikato region, results from the Auckland and Bay of Plenty regions showed statistically higher concentrations of Al in farmed soils compared to background ones (Table 1), indicating the dealumination process is not isolated to the Waikato region but is more widespread. However, the magnitude of the increase was much less in soils from the Bay of Plenty than that in soils from Auckland or Waikato. The reason for the reduced magnitude of the increase in the Bay of Plenty region is not clear but there are regional differences in climate, soil type and land use. Auckland is more northern and warmer than the others and the Bay of Plenty is more eastern and dryer. All 3 regions contain relatively young soils formed from volcanic tephra, while the Auckland and Waikato regions also contain soils formed from sedimentary rock. Pastoral farming is predominant in all 3 regions but horticulture (kiwifruit) is significant in the Bay of Plenty. Monitoring is continuing and the influence of the above variables on total recoverable Al will be further investigated once additional data is collected.

Table 1. Strong acid recoverable Al in farmed and not farmed soils from 3 regions of New Zealand

	Mean Al in mg/kg and (number of samples)		
	Auckland	Bay of Plenty	Waikato
Farmed soils	21000 (54)	16900 (79)	36700 (170)
Not farmed soils	13200 (15)	14100 (17)	20600 (23)
Enrichment Factor	1.6	1.2	1.8
P (pooled t-test)	<0.015	<0.015	<0.0001

Across the 3 regions, 71 farmed and 8 not farmed sites had been sampled twice, approximately 5 years apart (Table 2). There was a significant increase in Al for farmed soils ($p < 0.0001$), a mean increase of about 6000 mg/kg, or about 1000-1200 mg/kg/y. There was no significant change ($p > 0.05$) for not farmed soils.

Table 2. Trends in strong acid recoverable Al in farmed and not farmed soils

	Mean Al in mg/kg		p (paired t-test)
	Year 1	Year 5	
Farmed (n=71)	25200	31500	<0.0001
Not Farmed (n=8)	21600	17100	>0.05

The impact and significance of this dealumination process on soil properties, soil quality and productivity is still to be established. Given this process has been identified in some of the major farming areas of New Zealand, there is some urgency in making certain the actual mechanism, and ascertaining its effects on soil properties and implications to soil management.

Conclusion

The dealumination process is not isolated to the Waikato region but is also found in adjoining regions. This process may be influenced by climate, soil type and the type of farming, but assessing the influence these factors requires further data.

This process is relatively quick and strong acid recoverable Al is increasing in farmed soils with a mean increase of about 1000-1200 mg/kg/y.

The actual mechanism of dealumination needs to be verified, and its effects on soil properties and implications to soil management need to be ascertained.

References

Sparling GP, Rijkse WC, Wilde H, van der Weerden T, Beare M, Francis G (2002) Implementing soil quality indicators for land: Research Report for 2000-2001 and finial report for MfE Project Number 5089. Landcare Research Contract Report: LC0102/015. (Landcare Research, Hamilton).