Spatial variability of soil phosphorus in grazing systems

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Abstract. Phosphorus (P) use efficiency has been identified as a key issue for Australian grazing systems. This project examined the spatial variability in soil P concentration from two separate surveys of grazed pasture fields. A field on the central tablelands of NSW had a range in Bray P of 1.2 to 140 mg/kg and a COV of 107%. The other field on the northern tablelands of NSW reported a range in Colwell P from 13.0 to 121.1 mg/kg and a COV of 59%. Maps of the spatial variability of soil P demonstrated that there is a relationship with field elevation. Application of critical P values to both fields enabled an estimation of the value of site specific fertiliser management. For one field, fertiliser inputs could potentially be isolated to 37% and the other 56% if nutrient additions were targeted at responsive areas. The opportunity for increased fertiliser use efficiency through site specific management (SSM) warrants further investigation. Research is required into both the value of SSM and the techniques that might enable the development of this strategy.

Keywords: Phosphorus, spatial variability, site specific management, variable rate fertilizer.

Introduction

Phosphorus (P) use efficiency has been identified as a key issue for Australian grazing systems (Simpson *et al.* 2011). The spatial variability of soil P has been documented in pastures in other countries (McCormick *et al.* 2009; Fu *et al.* 2010) however this has not been widely studied in Australian grazing systems (King *et al.* 2006). Understanding the spatial variability in soil P could provide valuable insights into the potential for management strategies on a landscape scale. Of particular interest is the potential for site specific management (SSM) of fertiliser through zonal management (Simpson *et al.* 2011). This technique is now commonly used in the cropping and horticultural industries however there remains some question regarding how this management strategy might be implemented in grazing systems (Trotter 2010; Trotter *et al.* 2010; Simpson *et al.* 2011) and its potential benefits. This paper reports on two separate spatial surveys of soil P undertaken in two pasture paddocks in Australia and discusses the potential implications for SSM of fertiliser in grazing systems.

Methods

Two paddocks were surveyed to quantify the spatial variability in soil P. The "Panuara field" was a 40 ha paddock located on the central tablelands of NSW, Australia (33˚27'S; 154˚56'E). Field elevation ranged from 760 to 820 m and the site had an average annual rainfall of 809 mm. The soils whilst derived from siltstone parent material are highly variable in depth, with little or no soil on the ridges as compared to deep soil profiles (>2.5 m) in the valley floors. The soil texture for the surface soil was uniformly clay loam. Native pastures dominated the sward including *Microlaena stipoides* and *Austrodanthonia* spp. The site had a moderate history of superphosphate fertiliser allocation that was generally spread evenly across the field.

The "Kirby field" was a 47 ha paddock located on the northern tablelands of NSW, Australia (30˚25'S; 151˚38'E). Field elevation ranged from 1,081 to 1,134m with soils derived from granite parent material and an average annual rainfall of 788 mm. Native and naturalised pastures dominated the sward including *Bromus* spp, *Vulpia* spp, *Imperata cylindrical*, *Microlaena stipoides* and *Austrodanthonia* spp. The paddock has been subject to grazing primarily by sheep and, too a lesser extent cattle, for all of its known history. Long term fertiliser history was not available for this field however recent applications have been 125kg/ha of single superphosphate every second year spread by air.

Field sampling and laboratory analysis

Soil sampling of the Panuara field was undertaken in September 2007 across a 33 m grid providing a total of 311 samples. At each site 10 soil cores (25 mm wide and 100 mm deep) were collected from at 2 x 2 m area. Samples were bulked and subsampled for laboratory analysis (Bray P) (Rayment and Higginson 1992).

Soil sampling of the Kirby field was undertaken in May 2012 across a 100 m grid providing a total of 41 samples. At the site 20 soil cores (20 mm wide and 150 mm deep) were collected within a 1 metre radius of the sample point. Samples were bulked and subsampled for laboratory analysis (Colwell P) (Colwell 1963).

It should be noted that this paper does not intend to draw direct comparisons between the two fields in terms of actual soil P (the different P extraction methods preclude this) but rather focuses on the spatial variability found in each. Elevation maps were also developed at both sites

Table 1. Descriptive statistics for soil test values from Panuara and Kirby.

	Panuara field P (Bray)	Kirby field P (Colwell)
Number of samples	311	41
Mean (mg/kg)	21.0	30.6
Minimum (mg/kg)	1.2	13.0
Maximum (mg/kg)	140.0	121.1
Standard deviation (mg/kg)	22.6	18.1
COV (%)	107	59

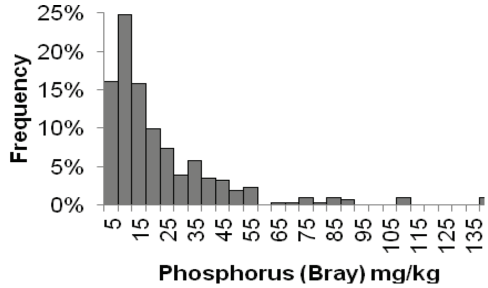

Figure 1. Frequency distribution of soil test Phosphorus (Bray) from Panuara field.

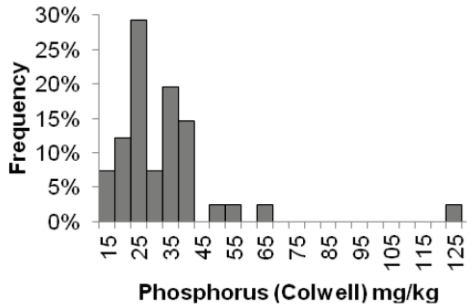

Figure 2. Frequency distribution of soil test Phosphorus (Colwell) from Kirby field.

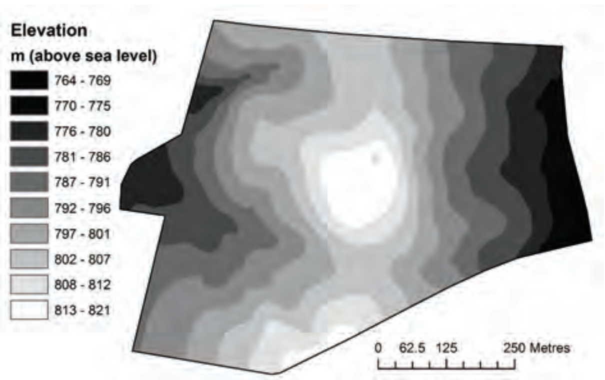

Figure 3. Elevation map for Panuara field.

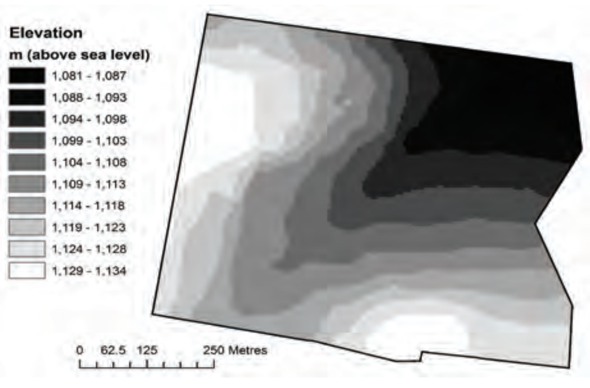

Figure 4. Elevation map for Kirby field.

using a differential GPS and are provided for comparison (Fig. 3 and 4).

Analysis and mapping

Descriptive statistics and frequency distributions of soil test data were developed for both fields. For the purposes of visualising the spatial variability of soil P the soil test values were interpolated using Spline fit with barrier (output cell size 10 m, barrier was 50 m buffer on paddock boundary) in ESRI ArcGIS (Redlands California). The spatial variability in potential P response through fertiliser addition was also was estimated by applying critical P values to the interpolated soil test data. For the Panuara field a critical P value of 10 mg/kg was applied (Hazelton and Murphy 2007) and for the Kirby field a critical P value of 30 mg/kg was applied (Holford and Crocker 1988).

Results and discussion

Summary statistics for the soil tests reveal a large range in soil test P values for both the Panuara and Kirby fields (Table 1). Whilst it is difficult to compare absolute values between both these sites and other studies due to differing laboratory analysis the COV does provide some indication of the degree of variability present between sites. The COV for the Kirby field (59%) is comparable to other studies (Fu *et al.* 2010 reported 63% and McCormick *et al.* 2009 57%). The COV for the Panuara field (107%) was considerably higher.

The distribution of P values from the Panuara field demonstrates a classic skewed trend that is commonly reported for soil P concentration (Fu *et al.* 2010). A similar trend was observed for the soil P test values from the Kirby field, however the tail was less pronounced, which was possibly due to a smaller sample size. The small numbers of high P concentrations which characterise these distributions are most likely the result of animal camping activities, although at both sites the high P extends beyond the areas obviously influenced by this.

The spatial variability revealed in the interpolated soil P data for both fields (Fig. 5 and 6) demonstrates similar trends across both fields when compared to elevation (Fig. 3 and 4). Small areas of high soil P concentration are isolated to the higher elevations whilst lower elevations are dominated by areas of reduced soil P concentration. Similar elevation related trends have been reported for P (Schnyder *et al.* 2010) however it is worth noting that this contrasts with the results of Stefanski and Simpson (2010). The increased nutrient deposition at higher elevations is most likely associated with livestock camping activities (Hilder 1964). Evidence of a relationship between soil P concentration and a readily measurable landscape attribute (elevation) across both sites suggests that there may be an opportunity to implement zonal fertiliser management

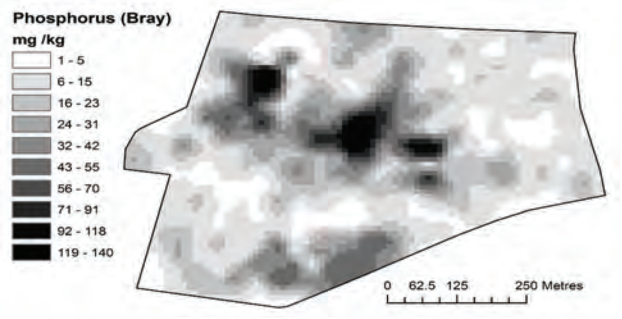

Figure 5. Spatial variation of soil P (Bray) across the Panuara field.

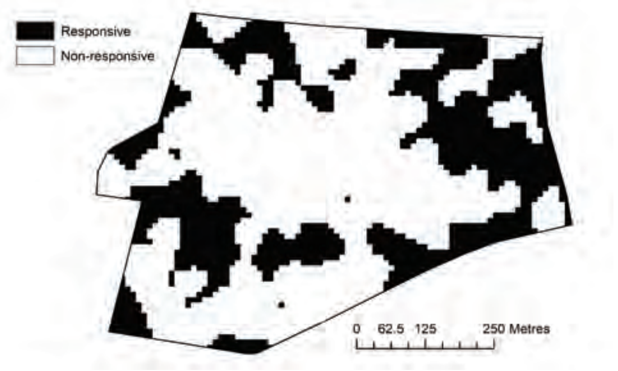

Figure 7. Potential P response map for Panuara field based on critical Bray value of 10 mg/kg.

strategies. However further research is required to understand the correlation between elevation, soil P and other soil and plant factors to determine exactly how zonal strategies might be developed and site specific management of fertiliser implemented.

By defining critical P values for both fields we are able to examine the potential value of site specific fertiliser management. Figures 7 and 8 reveal that large areas of both fields are expected to be unresponsive to the addition of P fertilisers. An examination of the mean soil test values indicates that on average they both exceed their respective critical P values (Table 1). This suggests that if a representative sample of soil was taken for both fields the recommendation would be to apply no fertiliser outside maintenance rates. An evaluation of the actual soil test data reveals that 37% and 56% of the samples may be responsive for the Panuara and Kirby fields respectively. If site specific management of P could be achieved and accurately targeted at responsive areas this suggests that fertiliser applications would be applied to 37% of the Panuara field and 54% of the Kirby field providing substantial savings and also potentially increasing production from these P limited areas. The obvious limitation of this analysis is that it does not take into account the spatial variability in species which may have different critical P values, nor does it take into account other factors which might limit pasture growth, particularly soil moisture.

Conclusion

This paper has demonstrated the large scale variability in soil P concentrations present in two representative fields of Australian grazing systems. In both fields there was some

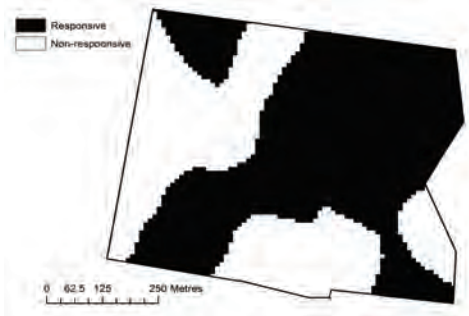

Figure 6. Spatial variation of soil P (Colwell) across the Kirby field.

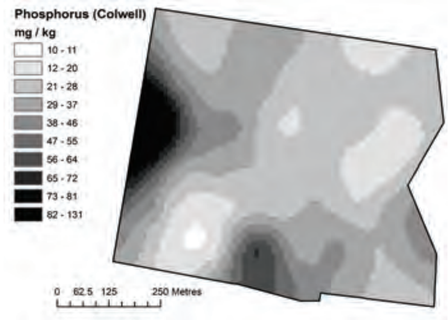

Figure 8. Potential P response map for Kirby field based on critical Colwell P value of 30 mg/kg.

relationship with elevation observed which warrants further investigation. SSM strategies that targeted only the responsive areas would result in only 37% of one field and 56% of another having fertiliser applied. This could provide substantial input savings and potentially increases in overall paddock pasture production. Further research is required into both how site specific management of fertilisers might be achieved and into the value in terms of more efficient fertiliser use and increased pasture production.

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