Uneven nutrient distributions in hillside paddocks indicate potential need for variable rate fertiliser applications to pastures

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Abstract

The distribution of topsoil pH and key macronutrients was examined relative to slope in three hillside paddocks on the southern tablelands, NSW. The soil was of a similar type at all sites and sufficiently acid that lime would be recommended. Exchangeable K concentrations increased up the slope at every site and were inadequate for maximum pasture growth in at least part of the paddock at two sites. Extractable P was the most uniformly distributed nutrient and was deficient for pasture production at all locations except in a hilltop sheep camp at one site. Gradients in P concentration were not found to be associated with slope as has been observed elsewhere. Differences in extractable S concentrations occurred between zones in some paddocks. S levels were low enough to be regarded as marginal or deficient for pasture growth at all locations except in the upper slope areas of one site. Exchangeable Mg and Ca concentrations often increased up the slope and were adequate for pasture growth at all sites. Potentially sodic soil was observed at the base of one paddock. The results indicated that at every site, a uniform application of fertiliser to address P-deficiency alone would be ineffective in lifting pasture productivity in some part, or the entire paddock due to irregularly-distributed deficiencies of either S and/or K. Variable rate fertiliser applications may be justified in pasture-based systems. Pasture productivity mapping is now well enough advanced to support such a development but mapping the plant-available nutrient status of soils is still an expensive and rate-limiting step.

Key Words

nutrient gradients, phosphorus, potassium, soil fertility, sulphur, variable rate technology.

Introduction

It has been known for some time that productivity gradients exist in many grazing paddocks (e.g. Hill et al. 1999) and as a consequence it is likely that application of fertiliser based on a single soil test representing the average fertility of the paddock may be intrinsically inefficient with respect to fertiliser use. The causes of variable productivity can be many. Nutrient (N, P, S and K) gradients are created by grazing animals typically as a result of grazing behaviour (Schnyder et al. 2009) and/or slope in hillside paddocks (e.g. Gillingham and During 1973) or as a result of repetitive stock movements, the location of feeding and watering points, or shade, etc (e.g. Matthews et al. 1994). In addition, uneven productivity is also associated with differences in topography, aspect, botanical composition, grazing preference, soil type and depth (Murray et al. 2007). Recently, Hackney (2009) has shown that as P-fertiliser prices increase, differential fertiliser applications combined with grazing management to ensure pasture is utilised adequately, will increasingly deliver economic benefits from paddocks that have uneven productivity

We examined the spatial variation in soil pH and the macronutrients likely to be required as fertiliser, in three hillside paddocks. The objective was to ascertain whether uneven nutrient distributions were likely to impact on the efficiency with which P-fertiliser would be used.

Methods

A hillside paddock with relatively a uniform gradient (Fig.1) and supporting permanent *Trifolium subterraneum*-based pasture was selected at random from each of three properties near Bookham and Binalong, NSW (ave. rainfall ~700 mm): "Marilba" (34^{o}46'18.5"S, 148^{o}42'30.9"E), SW aspect; "Emerald Park" (34^{o}42'03.0"S, 148^{o}39'14.5"E), E aspect; and "Kia-Ora" (34^{o}48'182.4"S, 148^{o}34'49.0"E), S aspect.

Soil samples (0-10 cm depth) were collected in May 2008 at 0, 100, 200 and 300 m intervals up the slope of each hill, from the base of the paddock. The soil in each case was a Yellow Kurosol (Isbell 1996) and derived from granite. Two replicate areas 30 m apart were sampled at each point by taking 15 soil cores which were combined, air dried and sieved through a 2 mm sieve.

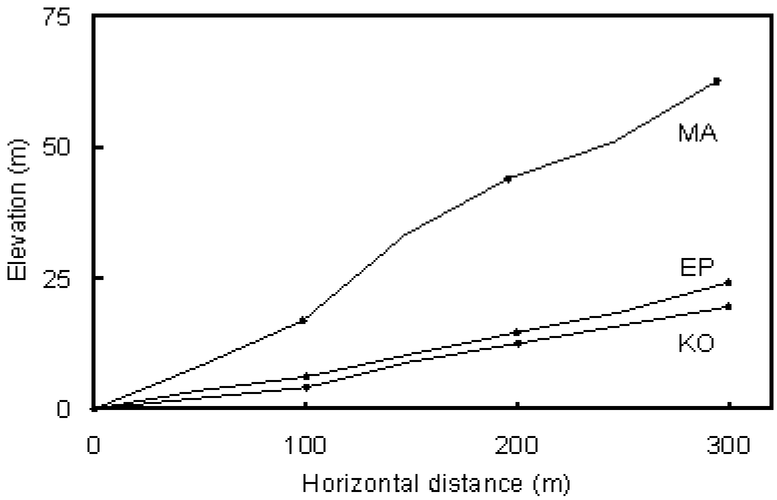

Fig. 1. Profiles and elevations of three hillside paddocks (Bookham district, NSW), selected

for soil sampling. Sampling locations are indicated by the closed circles. Heights above sea level of the location at the base of each hill were 600, 515, and 488 m, and the average hillside slopes were 12.4°, 3.6°, and 4.3° above horizontal for Marilba (MA), Kia-Ora (KO)

and Emerald Park (EP), respectively.

The soil samples were analysed for pH ($CaCl_2$) (Rayment and Higginson 1992), extractable P (Colwell 1963), extractable sulphur (KCl40) (Blair et al. 1991), and exchangeable potassium, calcium, magnesium and sodium (1M NH_4Cl) (Rayment and Higginson 1992).

Results

All three sites were of similar soil type but differed to varying degrees in their soil pH and the distributions of nutrients (Fig. 2). The soils were acid with very low pH conditions encountered at "Kia-Ora". In all cases, lime would be recommended for these soils, and varying rates of lime would be required to ameliorate low pH depending on location within each paddock.

The concentrations of exchangeable K measured in the topsoil increased uniformly up the slope at every site. Although a clear gradient in K concentration was observed at "Marilba", the levels of K in this paddock were adequate for maximum pasture production. However, at "Kia-Ora" and "Emerald Park", K was below the critical level needed to achieve 95% of maximum pasture production (Gourley et al. 2007) on the lower levels of the hillside paddocks with K concentrations increasing to either marginal or adequate concentrations toward the top of the slope.

Extractable P was the most uniformly distributed nutrient but was inadequate for maximum pasture production (Gourley et al. 2007) at all locations and sites except in the sheep camp at the top of the hill at "Marilba". Although some significant differences in extractable P levels were found, the data did not indicate gradients in P concentration associated with slope as has been observed elsewhere (Gillingham and During 1973; Schnyder et al. 2009).

Extractable S concentrations differed between zones in some paddocks but not others. There was no evidence of uniform gradients in S concentration associated with slope, except, perhaps, at "Marilba". Extractable S concentrations were in most cases low enough to be regarded as marginal or deficient for pasture growth (Gourley et al. 2007) with the exception of the upper slope areas of the "Marilba" hillside paddock.

Exchangeable Mg concentrations increased up the slope at all sites, although at “Emerald Park” only very minor changes were recorded. Mg levels were adequate for pasture growth at all sites (Peverill et al. 1999).

At two of the three sites ("Marilba" and "Kia-Ora") exchangeable calcium concentrations increased up the slope but the change in concentration at "Kia-Ora", although significant, was small. No differences were found between zones in the paddock at "Emerald Park".

A high Na concentration was measured at base of the paddock at "Emerald Park" indicating that the soil could be classed as sodic, (exchangeable sodium percentage (ESP) = 6.2), with only minor differences in the distribution of Na at all other locations and sites (Peverill et al. 1999).

Discussion

The results of the soil tests returned for all of the paddocks indicated that they had not been fertilised regularly or recently. Deficiencies in P, S and K were observed with P-deficiency being essentially uniform in every paddock except for a large sheep camp at "Marilba". This contrasts with observations of major transfers in P upslope in hillside paddocks but may also reflect the fact that these paddocks have had a poor fertiliser history thus constraining the opportunity for P transfer by livestock, or because they were predominantly on gently-sloping hills.

In every case, a uniform application of fertiliser to address P-deficiency alone would be ineffective in lifting pasture productivity in either some part, or the entire paddock due to either S or K deficiency or deficiencies in both elements. The use of a "dual-purpose" fertiliser such as superphosphate (P and S), which is commonplace, would not have adequately addressed nutrient distribution issues at two of the three sites. At "Emerald Park", potentially sodic soil at the base of the paddock could also constrain response by pasture to P application and a gypsum application to improve soil structure may also be advised.

Nutrient distributions in these paddocks were for the most part irregular. The only exception to this was the distribution of K, the concentration of which increased progressively with elevation. The results indicated a

need to ideally adjust both the fertiliser amounts and elemental mixtures to adequately address the fertility

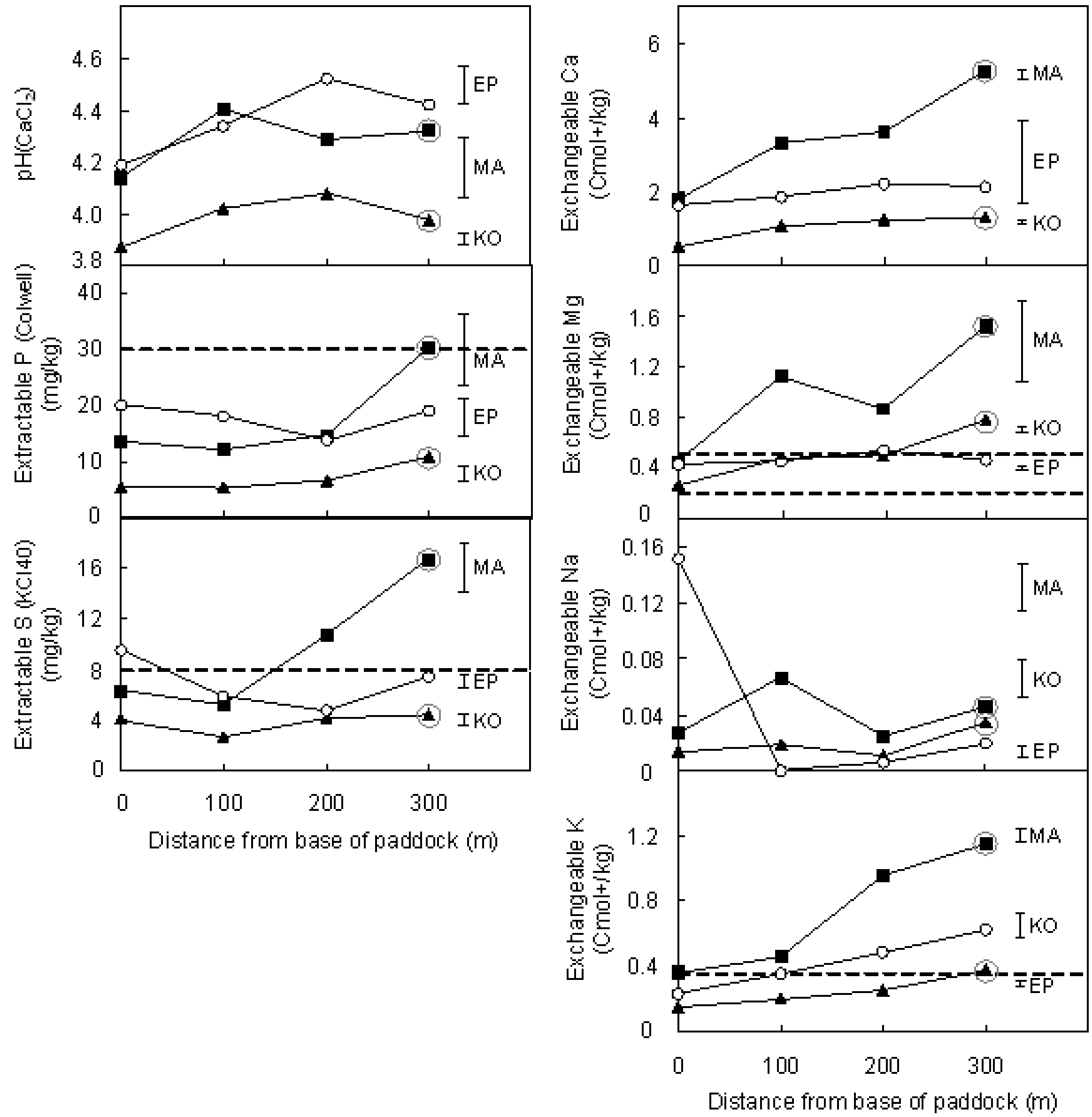

Figure 2. Soil pH and concentrations of nutrients in topsoil (0-10 cm) at locations measured from the base of hillside paddocks in the Bookham area of NSW. MA (■) "Marilba", EP (○) "Emerald Park", and KO (▲) "Kia-Ora". Bars represent LSD (*P* = 0.05) for comparisons between locations at each site. Symbols that are circled indicate locations that were near ("Kia-Ora"), or within ("Marilba") a sheep camp area at the top of the hill. Dashed horizontal lines indicate critical nutrient concentrations for 95% of maximum pasture production (references cited in text). The two thresholds for Mg are for sandy (lower) and clay soils (upper).

issues in different zones of the three paddocks. The situation is analogous to uneven yield distributions in cropping paddocks which, when managed using variable rate technology, can significantly improve the net profitability of a crop (e.g. Passioura 2002). The use of yield mapping in crops is increasing rapidly. However, it is less common to monitor productivity gradients in pastures. Where large and easily identified differences in soil fertility can be identified (such as livestock camp areas), fertiliser rates can be adjusted relatively easily (e.g. Gillingham and During 1973).? However, irregular nutrient or productivity patterns need to be mapped using technology such as ground level, airborne or spaceborne canopy reflectance sensing devices (e.g. Hill et al.1999; Murray et al. 2007; Trotter et al. 2010).? Combined with GPS technology, productivity maps could enable variable rate fertiliser delivery in grazed landscapes.?

Conclusion

There is growing evidence that variable rate fertiliser applications may be justified in pasture-based systems and pasture productivity mapping is now well enough advanced to support such a development. Uneven nutrient distributions are a likely cause of irregular productivity patterns. However, presently plant-available nutrient status of soils cannot be mapped remotely and the spatial mapping of nutrient gradients (e.g. Kozar et al. 2002) to underpin variable fertiliser rate decisions is an expensive and rate-limiting step. In addition, irregular pasture productivity patterns are not always associated with nutrients alone and it will be important to be able to identify, rank and map all potential constraints to production for accurate application of variable rate fertiliser technology.

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