Factors affecting pasture productivity in topographically variable landscapes – implications for pasture input management

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Abstract

Seventy-three sampling locations (38 on the north-aspect, 35 on the south-aspect) in a topographically variable landscape paddock on the Central Tablelands of NSW were monitored to determine the effect of soil chemical and physical parameters and botanical composition characteristics on pasture production. Stratification of sampling points into regions based on landscape features (aspect and position on slope) showed pasture production varied significantly between strata within the paddock. In some instances, the difference in production between strata was greater than between aspects and was attributable to a combination of soil physical (principally those associated with waterholding capacity) and botanical composition (legume content) factors. Exchangeable aluminium, while not identified as an indicator of pasture productivity in initial analysis, was the main determinant of production when only soil chemical parameters were considered. Exchangeable aluminium in association with ability of soil to hold moisture were found to strongly influence legume content. The results of this study indicate that greater consideration of a range of factors, other than soil available P, are required to determine pasture production potential in variable landscapes. Further, researchers and advisors need to be cognisant of such factors in determining optimum fertiliser application strategies in such landscapes to optimise pasture production, livestock production and economic return on investment. This is particularly important as concurrent studies at this site found that, despite deficiency of available phosphors at all sampling locations, only two regional strata were responsive to P-application. The study findings also highlight the insidious impact soil acidity and associated aluminium toxicity on pasture production in high rainfall regions of southern Australia.

Key words
Pasture production, soil acidity, variable landscapes

Introduction
Variable landscapes, where cropping is precluded due to topographic characteristics cover large areas of the medium and high rainfall regions of south-eastern Australia. Livestock are the predominant source of farm income in such areas. Proximity to major metropolitan areas and associated demand for 'lifestyle' farms result in relatively high land prices (Behrdent and Eppleston 2011). Land acquisition as a means for increasing production can be cost-prohibitive for full time commercial farmers. To remain viable, farmers need to increase productivity per unit of land.

Traditionally, superphosphate has been used to stimulate pasture production in the abovementioned regions. The predominant legume found through these areas has historically been subterranean clover (*Trifolium subterraneum*). However, changing climatic conditions, specifically less reliable autumn breaks and unreliable spring rainfall has resulted in lower legume frequency and this is likely to have been exacerbated by reduced superphosphate application since the mid 1970's (Wheeler 1986, Howieson *et al.* 2000). Historical fertiliser were generally undertaken in discrete areas of the landscape on either fully improved exotic sown pastures, or pastures containing high levels of exotic legumes. Many of these pastures have now reverted to a naturalised state (Garden *et al.* 2000). Historic fertiliser studies did not take account of differences in microclimate and soil conditions (physical and chemical), which are a feature of variable landscapes (Hackney 2009). In studies on the Central Tablelands and Monaro regions, Hackney (2009) reported only six out of twelve discrete locations in variable landscape studies were responsive to uniform application of superphosphate despite all having sub-optimal available Colwell available P. Subjectively, lack of response was attributed to differences in botanical composition, soil chemical parameters (other than P-availability) and soil physical conditions. The degree to which these parameters affected response could not be objectively quantified in that study which concentrated on discrete areas of the landscape.

Fertiliser is the highest management cost input in variable landscape regions. Optimising returns from such an input, requires application strategies which consider the productive capacity and ability of different landscape areas to respond to fertiliser application need to be developed. In order to develop such strategies, a better understanding of the factors driving pasture production in variable landscapes is needed. This paper describes an experiment undertaken in a variable landscape on the Central Tablelands of NSW to determine the effect of soil chemical and physical parameters and botanical composition factors on pasture production.

Materials and Methods
The study site (20 ha) was located on the Central Tablelands of NSW (34°01' S, 149°33'E), longterm average annual rainfall of 830 mm. Soil across the site was a Kurosol and had a native perennial grass base with microlaena (*Microlaena stipoides*) the most prevalent grass. Subterranean clover (*Trifolium subterraneum*) had been introduced to the site during the 1960's via aerial application. Capeweed (*Arctotheca calendula*), flatweed (*Hypochaeris radicata*) and sorrel (*Acetosella vulgaris*) were the most prolific broadleaf weeds encountered. The paddock was broadly described as having north and south facing slopes of approximately equal area and within each aspect, east and west-facing aspects were also present.

Permanent sampling locations (73) were established across the north and south aspects on a regular grid. At each sampling location, measurement of location slope, aspect orientation, collection of soil for chemical analysis (0-10 and 10-30 cm), and soil particle fraction > 2mm were taken (0-10 cm),and penetrometer resistance at field capacity was measured. In addition, at every alternate sampling location, total soil depth and coarse soil particle fraction (CPF) > 2mm (30-50 cm and 50-80 cm) was assessed. Pasture production was assessed via direct cutting and drying at 80°C for 48 hours. Botanical composition was assessed at herbage harvest at individual species level. For the purposes of analysis, species were then grouped into the categories of 'perennial grass', 'annual grass', 'broadleaf weed', 'subterranean clover', and'other naturalised legumes'. Previous site studies (Hackney 2009) had shown more than 60% of total annual herbage production at this site occurred in spring, and therefore production for this study was monitored from 1 September to 30 November 2003.

For the purpose of data analysis, sampling points were stratified into eight regions based on aspect and slope position giving localities north upper (NU), north-north (NN), north-west (NW), north-east (NE), south upper (SU), south-south (SS), south-west (SW) and south-east (SE). Such subdivision represented a probable strategic fencing strategy to minimse over- and under-grazing by livestock. To investigate the relative importance of soil chemical and physical parameters, and botanical frequency properties on herbage production, a regression tree was fitted using least squares in Systat 12 using all measured parameters from the 36 sampling points where soil was sampled to 80 cm. No more than 10 splits were permitted and terminal nodes had to contain 5 or more units. Minimum split and split proportions were set at 0.05. In subsequent analysis, soil pH, total cation exchange capacity (TCEC), Al as a percentage of total cation exchange capacity, available P, available S, available K and organic carbon were fitted as factors assessing relative importance of soil chemical attributes on herbage production.. The regression tree model reports a proportional reduction in error (PRE) which is analogous to r^2 fitted in a regression equation (Shalizi 2006).

Results
Inclusion of all measured parameters in the statistical analysis showed subterranean clover frequency and factors associated with soil water holding capacity were the main factors affecting pasture production (PRE=0.79) (Figure 1). Areas with low subterranean clover frequency (<28%) produced the least herbage. Most of these areas were located on the north-facing slope. In contrast, the most productive areas were located on the south-facing slope – either facing due south, south-east or upper south slope without a westerly influence. No soil chemical factors were identified as influencing herbage production when all factors were considered simultaneously. When only soil chemical factors were considered in a separate analysis, exchangeable aluminium, exchangeable sulphur and organic carbon were the major factors affecting production, but PRE in this case was only 0.53. Soil available P was not a factor affecting productivity in the analysis. In a separate regression tree analysis, soil depth, exchangeable aluminium and presence of other legumes were found to be the factors affecting subterranean clover frequency (PRE=0.73).
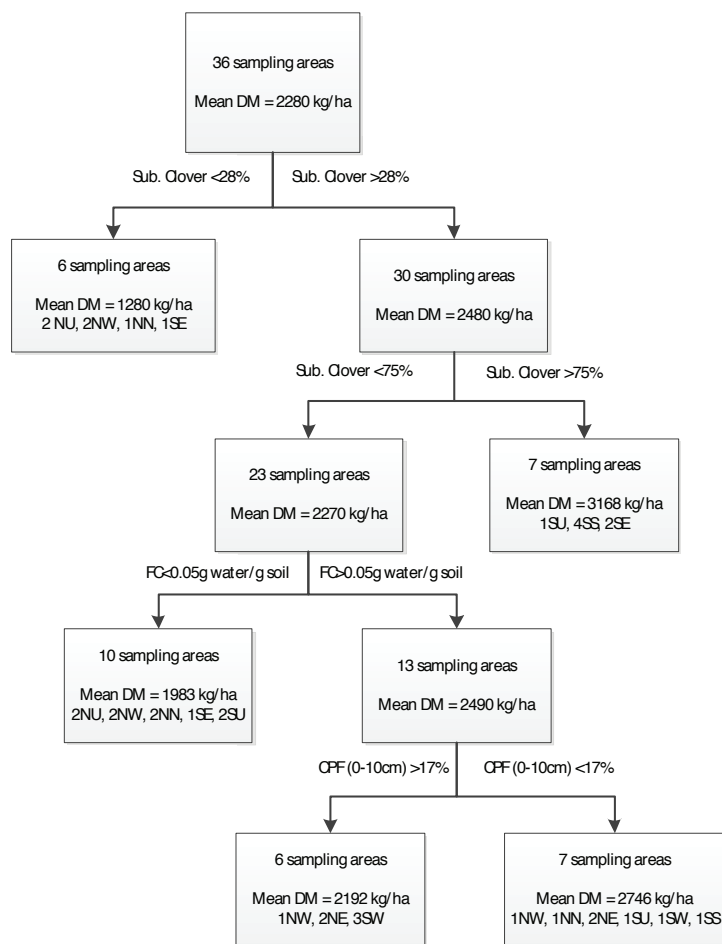
Figure 1. Spring herbage production as estimated from soil chemical and physical parameters and botanical composition for 36 sampling areas located in eight regions of a native perennial grass-based pasture at Burraga NSW in 2003. (Key: Sub clover = Subterranean clover, FC=field capacity, CPF= coarse particle fraction-the percentage of particles >2mm diameter. See the text for the system of classifying the sites according to aspect/slope).

Discussion

The influence of legume content on pasture productivity in combination with application of P-containing fertiliser has long been known (e.g. Whittet 1925). In this study, legume content was found to be a more important indicator of pasture production than was the level of P. Hackney (2009), in a concurrent study on this site, reported a response to application of superphosphate in only two of the eight strata despite all having sub-optimal levels of P. The results presented here should not imply that P-fertiliser is not an important consideration in influencing pasture production. Rather, it is likely that other factors are limiting the ability of resident pasture species to respond to applied P. For example, the ability of soil to hold sufficient moisture to respond to applied fertiliser, or the ability of plant roots to adsorb this P. Similar results have been reported by Zhang et al. (2005) in a New Zealand study where soil fertility, specifically available P and N, were found to be third and fourth tier determinants of production behind factors such as spring rainfall and slope (capacity to harvest moisture). These latter factors were found to be the main determinants of pasture production in variable landscapes.

When only soil chemical factors were used in the statistical analysis, exchangeable aluminium was found to be the major factor defining pasture production. The site used in the study was, in general, highly acidic with pH_{Ca} range of 4.2-4.6 across strata and associated exchangeable aluminium of 5-23%. Subterranean clover root growth, survival of associated rhizobia and therefore capacity to respond to applied P would be compromised under such conditions (Helyar 1991, Howieson *et al*. 2000). Highest productivity locations had the lowest coarse particle fraction and deepest soil (based on mean strata values). These sites also had highest subterranean clover content. Thus, subterranean clover plants in these strata were able to some extent to overcome the sub-optimal soil chemical conditions through access to higher moisture levels. Interestingly, the subterranean clover content required to achieve highest herbage production was over 75%. Recommendations for perennial grass-annual legume composition generally suggest legume content of

30-40% (Clements *et al*. 2000). It is probable in this study, that a higher percentage of legume was required to achieve greater production due to individual plant efficiency with respect to fixing N. Thus, a higher proportion of legume would be required to supply fixed nitrogen to non-leguminous pasture components. The suppressive effect of aluminium on subterranean clover production at this site was confirmed by the separate analysis where highest subterranean clover frequency was found in areas with lowest aluminium. This suggests exchangeable aluminium issues need to be addressed prior to the majority of the site having any capacity to respond to P-fertiliser application. However, other major limiting factors, such as soil depth, should not be ignored in an attempt to achieve an overall fertiliser response.

Lowest productivity areas were generally located on the north-facing slope and highest productivity on the south-facing slope. This is similar to findings of New Zealand researchers in variable landscapes (e.g. Radcliffe 1982). Hackney (2009) reported significantly shallower soil with a higher coarse particle fraction on the north compared to south-facing slope. Intermediate productivity areas were composed of sampling points from a range of strata indicating it can be difficult to define pasture productivity simply by locality. Radcliffe (1982) also reported variability within strata to be as great, or greater than that measured between aspects.

The implications of this study are important for allocation of inputs in variable landscapes. Greater appreciation of areas within a landscape to provide one of the fundamental resources for plant production – water, should be a primary consideration in estimating productive capacity. Legume content, too, is undisputedly a key factor affecting pasture production. However, the capacity of legumes to respond to management inputs, particularly fertiliser, may be limited by soil chemical properties and their interaction with root growth. While the legume plant may superficially appear to be healthy, as in this study, it is probable that root growth was stunted, thus rendering the plant less able to harvest nutrients and tolerate seasonal dry spells. Additionally, rhizobial survival and thus nitrogen fixation could be limited by soil acidity. This would then limit the potential for plants to respond to fertiliser addition. Consideration should also be given to optimising pasture composition in such landscapes. It may be that plants more able to tolerate soil acidity and infertility would be advantageous. Given the impact microclimate can have on grazing behaviour (Blackshaw 2003)in variable landscapes, the role of subdivisional fencing in conjunction with strategic, differential fertiliser application should not be ignored.

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