Why fertilise native pastures?

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Abstract: *Fertiliser use in recent decades has been in decline and largely confined to establishing or maintaining production from improved or highly modified pastures. Recent improvements in market conditions and ongoing financial pressures have served to increase both the opportunity and imperative to consider fertiliser use to extract the maximum sustainable economic yield from all pasture types including native pastures. While the addition of fertiliser to native pastures is not new, commodity and input price structures mean the economic return should be assessed case by case. Increased awareness of the biodiversity values of native grasslands and pastures has also served to broaden the focus of research into the fertiliser impacts on species composition and implications for long term sustainability. Research in New South Wales has shown that fertilisers can increase the economic return without compromising the sustainability of the native pasture base, especially where systems include strategic rest from grazing.*

Key words: phosphorus, productivity, profitability, species composition, sustainability

Introduction

Recent decades of poor wool prices, along with extended drought periods, have served to reduce the investment of graziers in fertiliser for pastures generally and for native pastures especially. Fertiliser for native pastures has been perceived to be of little use during drought periods and the savings have often been redirected to the purchase of feed supplements during these times. Increasingly, diminished carrying capacity in the decade to 2010 was frequently blamed on drought, but evidence suggests that diminished soil fertility levels were at least partially to blame (P Graham pers comm.).

Considerable research has been conducted in recent years demonstrating the ongoing benefits of phosphorus (P) fertiliser in achieving and maintaining higher levels of production from native pastures (Graham 2010; Garden *et al.* 2003; Lodge *et al.* 2003: Michalk *et al.* 2003). At the same time questions were raised as to the effect of fertiliser on the species composition of these systems, with regard to increasing the introduced annual grass and broadleaf weed components at the expense of the native grasses and forbs (Garden *et al.* 2003; Hill *et al.* 2004; Dorrough *et al.* 2008). In most cases, trends have been equivocal based on short-term (≤ four years) replicated data or based on qualitative survey data incapable of establishing causal relationships.

In the Monaro region of New South Wales (NSW), 70% of pastures are based on native species and are the mainstay of livestock production. While it is well established that improvements in soil fertility can increase pasture production (Gourley *et al.* 2007) this needed quantifying for native pastures on the Monaro. The Monaro Research, Development and Demonstration of Sustainable Grassland Management Project (MGP) was designed to determine if productivity could be increased without compromising the composition and biodiversity values of these native pastures.

Materials and methods

Environment

The research was conducted over a six year period from 2004 to 2010. The MGP research was conducted at two sites, representing two distinct soil types with species composition characteristic of the region. The Berridale site had a coarse textured yellow chromosol soil (Isbell 2002) of igneous origin deficient in both P (18 mg/kg Colwell) and sulfur (S) (<2 mg/kg KCl 40). At the Bungarby site the soil was a brown dermosol derived from basalt with moderate P (47 mg/kg) and low S (4 mg/kg).

Historical rainfall in the region is spring/summer dominant. Average annual rainfall between 2004–2010 was 461 mm (347–605 mm) at Berridale and 521 mm (392–733 mm) at Bungarby. The 25 year median to 2004 was 508 and 492 mm at each site, respectively. While there was drought in 2006 and 2008–09 three of the seven years were above this median at both sites.

Pastures

Baseline species frequency was assessed in spring 2004. Pastures at Berridale were quite diverse with 124 species present in quadrats sampled during frequency counts. Of these 72 were native species; (25 native grasses dominated by *Austrostipa* and *Rhytidosperma (*formerly *Austrodanthonia*) species, 45 forbs and 2 shrubs). The remaining species were exotic broadleaf weeds, annual grasses, perennial grass weeds and legumes). On a biomass basis, 77% of the pre-treatment biomass was made up of native perennial grasses and 5% was native forbs, but just 2% was naturalised annual grasess (mainly *Vulpia* and *Aira* spp.). At Bungarby the strongly dominant species was *Poa sieberiana* which occurred in 91% of the 720 survey quadrats and accounted for 86% of the pretreatment biomass. Despite this dominance a total of 91 species occurred in the initial frequency survey; 51 were native (15 grasses, 35 forbs and one shrub) and of the remaining 40 exotic species 10 were grasses and 30 were forbs.

Treatments

Each site had nine, five ha paddocks arranged as three replicates of three treatments. The treatments were nil (control), low fertiliser (local practice or minimum input) or high fertiliser (rapid input of soil fertility), with treatments differing by each site depending on local soil conditions. Rather than having fixed rates of fertiliser for the study duration, treatments were based on reaching target soil P and S levels. All fertilised treatments also had subterranean clover (*Trifolium subterraneum*) broadcast with the first application. At Berridale, the initial fertiliser applications were nil, 125 kg/ha (low) and 250 kg/ha (high) of molybdenumised superphosphate with the intent of reaching the target soil P of 27 mg/kg (Colwell) and S levels of around 8 mg/kg (KCl 40) sooner on the high treatment. Once target soil levels were reached fertiliser rates were lowered to maintenance levels. A major question was whether higher initial rates of fertiliser result in a greater decline in native pasture species. At Bungarby common practice was to fertilise only with a source of S, while assuming P to be adequate. The treatments at this site compared the effect of applying gypsum at 125 kgS/ha/yr to that of applying the same rate of gypsum plus superphosphate at 125 kg/ha/yr until target soil P levels were reached (P Colwell 41 mg/kg, S 8 mg/kg KCl 40) and then maintenance rates of P and S thereafter.

At each site all paddocks were set stocked with a randomised allocation of Merino wethers at the historical stocking rate of the original paddock. These rates were maintained for the first year and subsequent stocking rates altered with reference to differences between the weight, fat score and wool production of the nil treatment compared with the fertilised treatments. The goal was to balance stocking rates such that the performance of individual animals was equal across all treatments at each site. When necessitated by drought paddocks were destocked, the timing of destocking being determined by ground cover thresholds and/or projected animal performance based on available herbage.

Measurements

At each site, herbage mass (total and green kg/ha), botanical composition (% and kg/ha) and ground cover (%) were recorded using BOTANAL following the methods of Tothill *et al.*(1992). These measurements were taken six to seven times per year by at least three observers each recording fifty 0.5 m quadrats along random transects in each plot. Toe-point herbage samples along random transects were collected for nutritive value testing around the time of each herbage mass assessment. Species frequency was recorded in late spring each year. All species were recorded for their presence in eighty 0.5 m quadrats along random transects in each plot.

Sheep were weighed and fat scored within a few days of all BOTANAL measurements. Individual fleece weights were measured at shearing each year with fibre diameter being determined using OFDA 2000 on mid-side wool samples. Dye-bands were applied seasonally at skin level on the mid-side to allow seasonal wool growth to be determined. Since OFDA 2000 measurements provide fibre diameter at 5 mm intervals along the staple seasonal fibre diameter was also derived. Weight and fat score were usually also assessed whenever animals were removed from and replaced in plots and dye-bands also applied so that the wool grown while actually grazing on the experiments could be calculated.

Economic assumptions

The economics were evaluated based on either median prices of wool and surplus sheep for the five years up to 2011 or on 2011 prices. Input costs were taken from the NSW DPI sheep gross margins published in 2011 and applied per dry sheep equivalent (DSE). In the analysis, fertiliser prices were the actual costs at the time of application. Economic scenario analyses used a spread cost of $540/tonne for superphosphate and $150/tonne for gypsum. The research evaluation used the actual wool cuts and fibre diameter grown while animals were present on the plots, while the scenario analyses used the average fleece weights and micron of the genotypes used in the research. Only the interest on the cost of additional livestock was included as it was assumed that the inventory value of the animals was the same as the purchase price.

Results and discussion

Pasture production

Data from the MGP (Figure 1) indicated small treatment differences in herbage mass, although the trend was toward higher herbage mass on the fertilised plots. This was especially evident in 2005 when animal numbers were the same across all treatments. Differential stocking rates after the first year of the experiment were perhaps the reason for the non significant differences in herbage mass

Unpublished data (P Graham and F Leech) from a long-term demonstration at Bookham near Yass has quantified differences in pasture growth for a typical southern tablelands environment. From 1998 to 2006, pasture growth rate was measured in a paired paddock comparison of an unfertilised natural pasture and one that had had annual fertiliser application starting with a capital application of 250 kg/ha of single superphosphate in 1994. Table 1 shows the monthly average growth for the normal growing season (April–November) was consistently higher for the fertilised treatment, although the differences for April and May were not significant. Importantly winter growth with single super phosphate was reliably double that with no fertiliser and is the single biggest factor contributing to increases in carrying capacity in this demonstration.

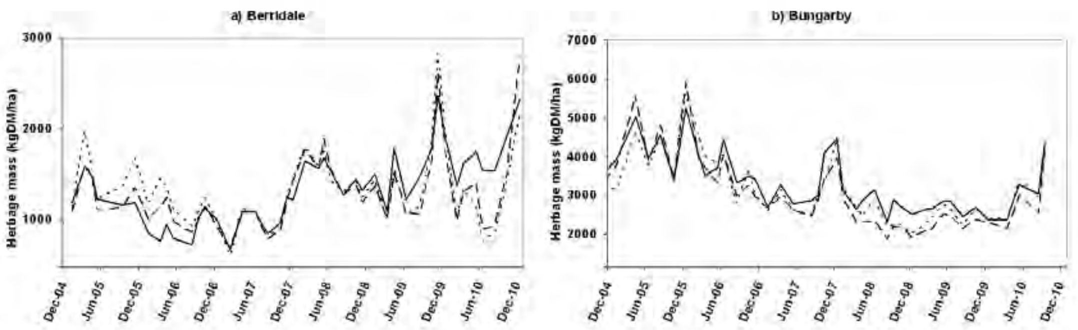

Figure 1. Total herbage mass for all years at the MGP research sites. Treatments are: Berridale, nil (solid line); low (dashed line), high (dotted line); Bungarby nil (solid line), S (dashed line), P and S (dotted line).

Since experimental data is usually presented in terms of herbage mass it is often confounded by differential stocking rates being applied to each fertiliser treatment. However, Michalk *et al.* (2003) found fertilised naturalised pastures accumulated greater herbage mass than unfertilised treatments and at a native pasture site near Yass, Garden *et al.* (2003) also reported significant differences in total herbage mass in the high fertiliser treatments.

Animal production

Animal production is a product of stocking rate and per head production. The MGP data showed a very rapid divergence in individual animal performance which only occurred after the application of fertiliser at each site (Figure 2). There was no significant difference in liveweight between low and high treatments at Berridale, but both were significantly higher $P<0.001$ than the nil treatment until the final stocking rate was reached in 2010. At Bungarby, although the trend was the same, differences were not significant $P=0.16$ until spring of 2007 in the second cohort of animals. Once stocking rates reached the new carrying capacity there were no further treatment differences in liveweight at either site. Trends in fat score closely paralleled liveweight (data not shown). Higher liveweight and fatness on the fertilised treatments suggest stocking rates could have been raised sooner.

Wool cut per head (Figure 3) also followed this pattern at Berridale with significant differences ($P<0.001$) between treatments persisting until 2010. Differences in fibre diameter were only significant ($P<0.011$) in the 2007 production year (data not shown). At Bungarby, wool cut per head had the same treatment trends, but were not significant ($P<0.016$). Production per ha increased with stocking rate although absolute production levels were severely hampered by drought and periods of destocking. By 2010, both high and low treatments at Berridale and the P and S treatments at Bungarby achieved approximately double the wool cut per ha of the respective nil treatment.

Similar increases in carrying capacity and land productivity were reported in other research. On the Bookham Grazing Demonstration (Graham 2006) stocking rates were increased by 75% in the first year of fertiliser application but fleece weights yield and tensile strength measures

Table 1. Average monthly pasture growth rates (kg dry matter/ha/day) recorded at the Bookham Grazing Demonstration from 1998–2006 inclusive.

	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.
Plus superphosphate	13	11	14	16	18	28	67	71
No superphosphate	6	6	7	7	8	13	26	35
t- statistic*	0.315	0.056	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

*Two tailed t-test of samples of unequal variance. Only years where at least one paddock recorded some growth were used.

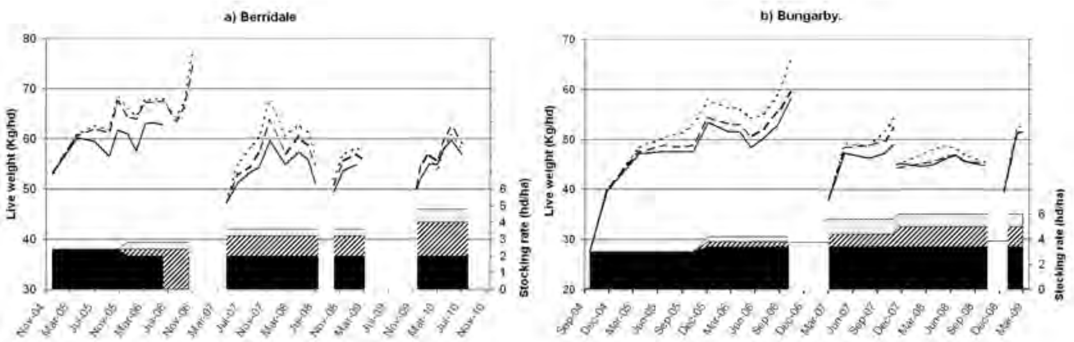

Figure 2. Sheep liveweight and stocking rate for each MGP research site. Nil treatment (solid lines and shading), low and S treatment (dashed lines and hatching), high and P and S treatment (dotted lines and stippling). Breaks in the data indicate drought destocking periods and changes in animal cohorts.

were still higher on the fertilised paddock. Averaged over 13 years the fertilised paddock carried 119% more stock and cut 113% more wool per ha. Garden *et al.* (2003) at the Yass site found that stocking rates for three rates of single superphosphate (62, 125 and 250 kg/ha) averaged 18, 57 and 86% higher, respectively than the nil treatment over four years. At Barraba in northern NSW, Lodge *et al.* (2003) found that, wethers grazing native pasture with subterranean clover and fertilised with superphosphate (125 kg/ha) were significantly heavier than the unfertilised control even at twice the stocking rate. The scale of these responses is not new, even in 1981–84 a paired paddock demonstration 'Super$ense' at Mumbil (near Wellington, NSW) ran twice the stocking rate on the fertilised natural pastures paddocks from 1982 onward, achieving a doubling in wool cut per ha despite severe drought conditions.

Stability of species composition

Data from Berridale (Figure 4) shows a signficant increase in total herbage mass of *Austrostipa* spp. on the nil treatment compared with the two fertilised treatments. This was not supported by the frequency data for which the only treatment effect was a decline in nineawn grass (*Enneapogon nigricans*) on the high treatment; a similar trend was also found in the herbage mass data. The overall treatment effects for naturalised legume was an increase on the fertilised treatments relative to nil. The mean frequency values for the low (0.691) and high (0.7505) treatments were significantly higher than that for the nil treatment (0.4953). There were also seasonally transient treatment differences in legume biomass with differences being greater in wetter spring and early summer periods. There were no significant treatment effects on naturalised annual grasses, but the biomass of native forbs was significantly higher on the nil treatment toward the end of the experiment although there were no species frequency differences among treatments. While treatments did not influence the biomass of broadleaf weeds the frequency data indicated that sorrel (*Acetosella vulgaris*) remained

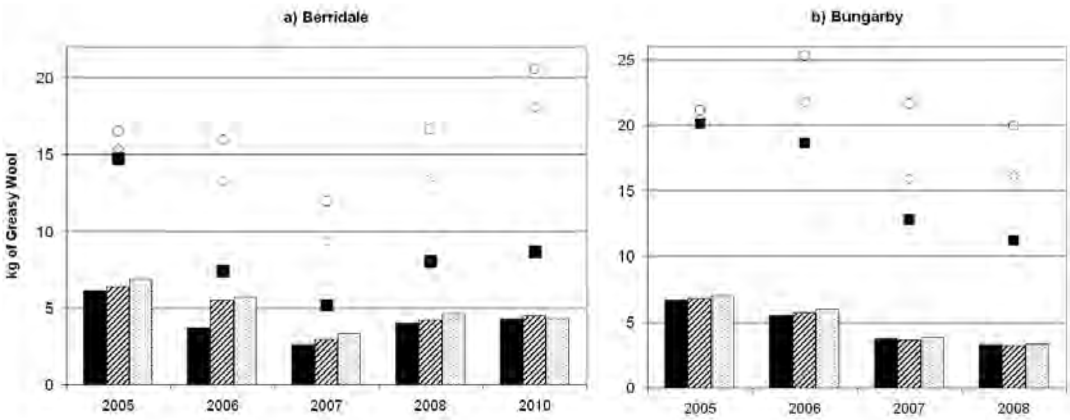

Figure 3. Greasy wool cut per head and per ha for each MGP research site; nil treatment (solid shading and squares), low and S treatment (hatching and diamonds), high and P and S treatments (stippling and circles).

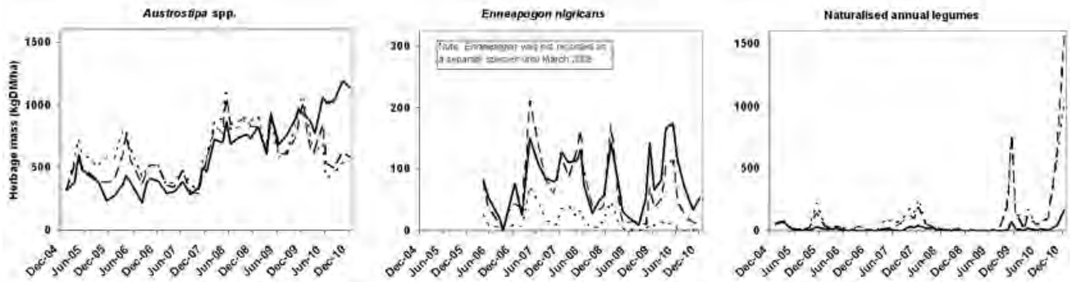

Figure 4. Total biomass of selected species at the Berridale research site. Treatments are: nil (solid line), low (dashed line), high (dotted line).

significantly higher on the nil treatment (0.4788) throughout the experiment than in the low (0.3521) or high (0.3184) treatments.

At Bungarby, there were no treatment effects on the herbage mass of the dominant native perennial grasses. However, the P and S treatment had significantly higher herbage mass of annual grass and both the P and S and S treatments had more naturalised annual legume. This was not reflected in species frequency counts, which largely showed no significant difference between treatments. Frequency of native forbs was also similarly unaffected by treatment except for narrow leaf New Holland daisies (*Vittadinia cuneata)*, which was significantly higher in the nil treatment (0.0131) than in the P and S treatment (0.0034). There were significant temporal effects on plant frequency for many species from all the plant groups. These effects were mostly related to the severe drought conditions in 2008–09 with a general decline through to this point and then a subsequent increase in 2009–10, although since animals could not be sourced in this period the grazing occurred as pulses of more intense grazing interspersed with long rest periods.

At the Bookham Grazing Demonstration (Graham 2006, and unpublished data 2007–11) pasture composition was monitored each August from 1995 onward (second year after first fertiliser application). Figure 5 summarises for each paddock the percentage incidence of the major species /groupings, bareground and litter across the period. Legume incidence was higher on the fertilised paddock, but this came at the expense of a decline in *Austrodanthonia* species. Also, the incidence of broadleaf weeds increased significantly in the unfertilised paddock.

The conclusions of Garden *et al.* (2003) on compositional changes were equivocal, reporting a decline in basal cover of native perennial grasses across the site and significantly lower basal cover on the high fertiliser treatment at the end of the research period. However, the medium and high fertiliser treatments also had significantly lower initial basal cover. Also the biomass of perennial grasses, although showing relative decline on the medium and high fertiliser treatments over time also experienced signficant recovery to values similar to the nil treatment over the final six months.

Dowling *et al.* (2006) reporting on research at Carcoar (NSW) found that the herbage mass of native perennial grasses was not different on a fertilised continuously grazed treatment compared with an unfertilised continuously grazed control, but annual grasses and legumes were significantly higher. Similar to the Bookham Grazing Demonstration (Graham 2006) there was also a decline in broadleaf weeds particularly flat weed (*Hypochaeris. radicata*). Despite the relative decline in the proportional biomass of perennial grass there was no difference in basal cover. The addition of tactical grazing (strategic summer rest) substantially eliminated the increase in annual grass biomass species and increased biomass of perennial grasses. Lodge *et al.* (2003) in northern NSW recorded a significant increase in basal cover of

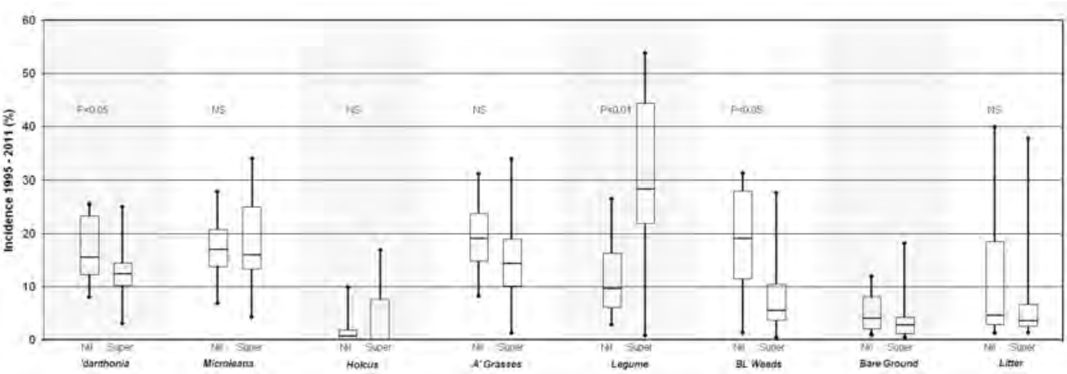

Figure 5. Box plots of pasture composition data sourced from the Bookham Grazing Demonstration (Graham 2010). Boxes represent the middle 50% of values and the line the median value. Whiskers show the full range of values across the 17 years.

redgrass (*Bothriochloa macra*) on both fertilised set stocked and unfertilised rotationally grazed treatments compared with an unfertilised set stocked control.

Ground cover

Ground cover was seldom <80% at either of the MGP sites, regardless of treatment (Figure 6). At Berridale, the low and high treatments maintained higher ground cover than the nil and this effect was signficant throughout 2006–08 and again in the later half of 2010. At Bungarby, there were treatment effects, with the P and S treatment tending to have higher ground cover than the nil treatment, while the S treatment maintained intermediate ground cover, which was frequently not significantly different from either the nil or P and S treatments. Similar positive impacts of fertiliser on ground cover have been observed by Lodge *et al.* (2003) despite stocking the fertilised treatment at twice the rate of the control.

Economics

While there is clear evidence of the potential increase in sustainable production from fertilising native pastures it should be noted that this does not always translate into an economic return. Incremental annual cashflow was calculated to determine economic returns of the treatments as applied in the Monaro research, but also we have extrapolated these results to commercially based strategies supported by the data.

For this research, stocking rates were raised gradually to discover the full improvement in carrying capacity without overstocking. At Berridale, the final stocking rate was not reached until year five and year four at Bungarby and this tended to preclude the potential economic outputs from being realised. Neither of the fertilised treatments at Berridale accumulated more cashflow than the nil treatment before the research was concluded. At Bungarby, the application of S alone almost broke even by year four, however the P and S treatment continued to lag behind. Economic data beyond 2008 was not available at Bungarby due to the sale of stock.

However, the early and persistent differences in animal performance between treatments (Figure 3) indicated fertilised treatments were understocked in the early years of the research. Economic modelling, (Figure 7) was based on fertiliser applied similarly to the Berridale low and the Bungarby S and P and S treatments. Three accelerated pathways toward the increased carrying capacity have been evaluated; 'slow' assumes final stocking rates are reached in year three with no change in year one; 'medium' reaches the final stocking rate by year two, with 50% of the change in the first year while 'fast' applies the final stocking rate immediately. Sensitivity to market prices was tested by comparing five year median prices ('median') as well as first decile ('2011') prices for wool (based on the weekly AWEX indicator by micron category up to March 2011) and sheep (based on the average weekly price for mutton and lamb recorded by the NLRS). The modelling presents cumulative profit differences

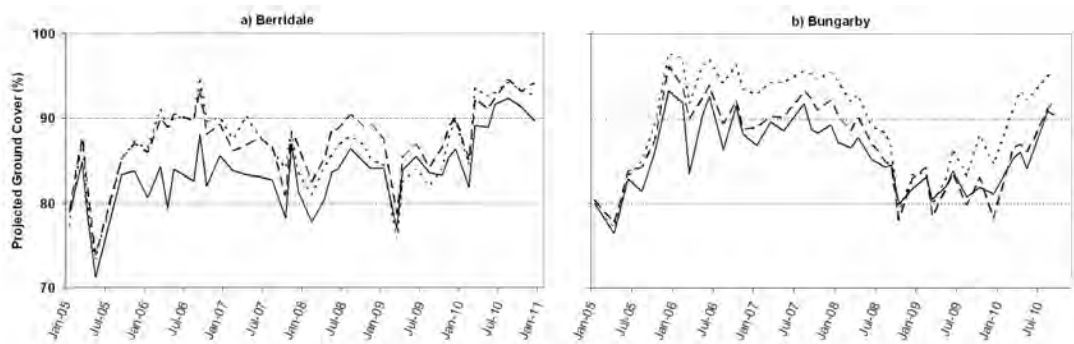

Figure 6. Ground cover on each of the Monaro research sites. Treatments are: Beridale; nil (solid line), low (dashed line), high (dotted line); Bungarby, nil (solid line), S (dashed line), P and S (dotted line).

compared with business as usual (equivalent to the nil treatments).

At Berridale, the slow/median scenario did not break even over a 10-year simulation. By substituting 2011 prices this stocking strategy broke even by year seven. The medium/median scenario also returned a profit in year seven, showing that this management option was as good as banking on first decile prices persisting. The fast/median scenario broke even in year five and returned 57% greater profit after 10 years. 2011 prices and a fast increase in stocking rate could increase the 10-year cumulative profit by around $250/ha.

At Bungarby, for the S treatment the slow scenarios broke even by year three. All other scenarios were profitable in their first year. The difference in the 10-year profit between a fast and a medium stocking rate scenario was less than $50/ha so a more conservative approach in this instance may prove less risky. The P and S treatment indicated that at median prices only the fast scenario generated any profit and broke even by year five. At 2011 prices, the slow strategy only generated useful profit by year nine and the medium scenario by year five, however the *fast* scenario returned a profit in the first year. Important to note is that the gypsum treatment returned 10-year profits of $250–300/ha at median prices while the P and S treatment could only achieve this using 2011 prices.

By comparison, at the Bookham Grazing Demonstration, stocking rates were raised by 75% in the first year of fertiliser application. At a base stocking rate of 6.3 DSE/ha this allowed the investment to return a profit in the first year. Cumulative profit over the 13 years to 2006 of $1024 compared with the business as usual strategy (Graham 2006). This economic performance illustrated that achieving immediate increases in stocking rate on top of a relatively high baseline carrying capacity (for an unfertilised native pasture) were important to the profit bottom line.

Many remaining native pasture areas are relatively low in natural carrying capacity being on shallow poorer quality soils and the economic response to fertilising is limited by this capacity. Table 2 presents economic modelling using the NSW DPI Pasture Cashflow Calculator (1.8a) and shows that at a base carrying capacity of 1 DSE/ha a decision to fertilise to raise carrying capacity will not return a profit after five years, regardless of the percentage improvement in carrying capacity. Similarly, if stocking rates improved by only 30%, no profit would accrue after five years, regardless of the base carrying capacity. Profitable decisions to fertilise native pastures only occur when the base carrying capacity is at least moderate (3 DSE/ha) and the increases in carrying capacity are >60%.

Conclusions

Results of the MGP research and other studies and research in NSW have consistently shown increases in carrying capacity >80% are achievable from addressing P and S deficiencies in native pasture systems. Whether these

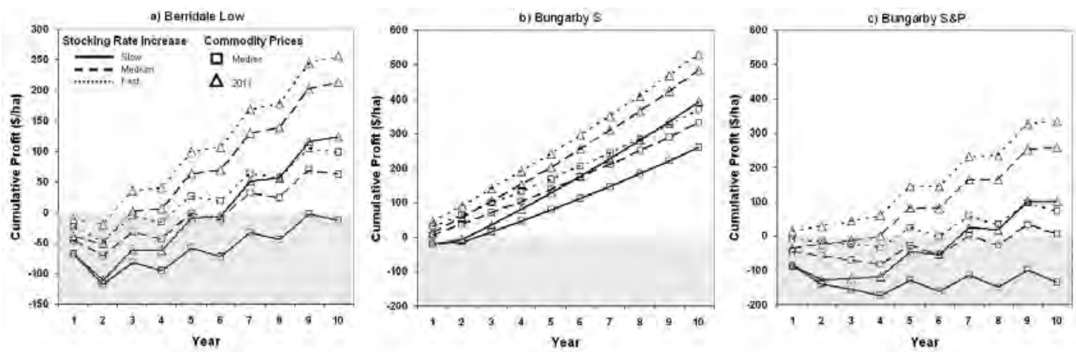

Figure 7. Cumulative profit projections for three Monaro systems and combinations of three stocking rate increases and two commodity price structures.

Table 2. Projected five year cumulative profit ($/ha) from fertilising native pastures running a Merino ewe breeding enterprise at a range of base carrying capacities.

Budgets assume capital fertiliser of 125 kg/ha (superphosphate @ $540/tonne spread) for the first two years and then maintenance @ 1 kgP/DSE in each subsequent year. Stocking rates were raised to half the new capacity in year one and to the full capacity in year two.

Increase in the number of ewes (GM = $31.46/DSE)	Base carrying capacity (DSE/ha)					
	1	2	3	4	5	6
30%	–153*	–136*	–118*	–102*	–83	–65
60%	–118*	–62	8	45	96	147
90%	–80	11	99	186	273	362

* Cumulative profit still in decline at year 5.

increases are economic will depend on many factors, including likely market conditions and fertiliser prices. Also of great importance is the actual increase in carrying capacity (DSEs/ha) and the strategies employed to quickly raise stocking rates in line with that capacity. Approaches to fertiliser decision making such '5 Easy Steps' (Simpson *et al.* 2009) will help in determining the value of fertiliser to all pastures including native pastures and give a basis to prioritise fertiliser use across the farm landscape.

While it is often stated that applying P is a destabilising factor in the composition of native pastures, findings of this and other studies conducted in NSW suggest the impacts were either minor or transient and that strategic rest from grazing can substantially offset this risk. The Monaro research has shown the composition of the common grasslands systems in this environment is remarkably robust, even with the addition of P and S to target levels. The strategy of fully destocking the two sites at times when drought conditions were compromising ground cover no doubt contributed to this stability and serves to remind us that on real farms a change in one practice (e.g. fertiliser use) should often be accompanied by corresponding changes in other management practices to gain the full benefits and to avoid potential pit falls.

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