Effects of fertiliser and grazing management on pastures, animal productivity and profitability

Geoffrey Saul

Agriculture Victoria, Pastoral and Veterinary Institute, Hamilton, Victoria 3300

Abstract: On-farm evaluations of productive pastures compared to typical farm pastures showed increases of 15-33% in gross margins for meat enterprises and spring lambing wool sheep, but autumn lambing wool ewes showed little benefit. Higher fertiliser rates increased the digestibility and protein content of herbage. The mechanism for this change is unclear but the improved herbage quality partially accounts for the higher animal production commonly seen on productive pastures. Tactical rotational grazing may allow carrying capacity to be increased by a further 20-30% compared to continuously stocked, productive pastures.

For the Grassland's Productivity Program - seeing is believing!

The Grassland's Productivity Program (GPP) involved 200 farmers across south-ern NSW, Victoria, southeast SA and Tasmania between 1993-97. Groups of 3-6 participants com-pared a "Productivity paddock" with a "Control paddock" on their farms. The Productivity paddocks had a higher rate of phosphorus (P) fertiliser applied, about 1 kg/ha/25 mm average rainfall (16-35 kg/ha). In addition, potassium (K), sulphur (S) and trace elements were applied depending on paddock history, soil and tissue results and test strip responses. Lime was applied where pH($CaCl_2$) was less than about 4.3 and pasture manipulation (resowing, heavy grazing in autumn, spraygrazing, drilling legumes *etc.*) was undertaken on a small number of paddocks to ensure composition (especially low clover content) did not limit the response to additional applied nutrients.

Control paddocks received the same management and fertiliser applications as had applied in the past 4-5 years, normally 0-15 kg/ha P with some S and limited amounts of K or trace elements. Both paddocks were set stocked and livestock weighed and condition scored regularly. Stocking rates were adjusted with the aim of maintaining livestock under similar pressure in both paddocks. This grazing pressure adjustment normal-ly involved increasing the stocking rate of the Productivity paddocks though in some instances, it became apparent that the initial carrying capacity of the Control paddock was overestimated.

Records of stocking rates, liveweights, herbage mass, livestock productivity, supplementary feeding and paddock and stock inputs were maintained by the producers to allow gross margins to be calculated for the paddocks. For these calculations, fertiliser was fully costed in the year of application though a portion of the response would be expected to continue in future years. Returns from each paddock were calculated from actual wool and stock sales where possible or valuations where stock were retained on farm. Where lime or pasture resowing was undertaken, costs were spread over 15 and 10 years, respectively. In addition to the normal costs included in gross margin analyses, (feed, fertiliser, animal health, animal management, herbicides *etc.*), interest on the value of the additional stock carried on the Productivity paddock was deducted together with additional sire and replacement costs of the livestock.

Results

Table 1 shows the gross margins calculated for the Control and Productivity paddocks and "return on investment". This latter figure was calculated as the *extra* \$ returned per *extra* \$ spent; *ie.* \$1.25 = amount returned per additional \$1 spent on the Productivity paddock. The beneficial effects of the Productive pastures, as measured by gross margin differences, was greatest with spring lambing ewes, especially meat sheep. These enterprises make efficient use of the large amounts of high quality herbage grown in these paddocks in spring. The higher gross margins from meat sheep is not unexpected, given the relative returns from meat and wool. Caution must be taken when comparing the absolute gross margins between different enterprises as meat sheep tended to be run in higher rainfall areas than wool sheep. Return on investment showed similar trends to the gross margins, with higher returns

Table 1: Gross margins ($/ha) and return on additional investment in GPP paddocks.

Enterprise	No. of farms	Gross margin ($/ha) Control paddock (Standard deviation)	Gross margin ($/ha) Productivity paddock (Standard deviation)	Additional $ returned/ additional $ invested
Autumn calving cows	6	257 (93)	295 (96)	1.41
Spring calving cows	4	172 (83)	213 (67)	1.44
Steers	3	389 (89)	442 (150)	1.90
Autumn lambing, meat ewes	12	294 (121)	359 (136)	2.07
Spring lambing, meat ewes	16	347 (157)	462 (172)	2.18
Autumn lambing, wool ewes	9	133 (63)	138 (61)	0.94
Spring lambing, wool ewes	50	235 (137)	297 (150)	1.63
Wethers	15	172 (97)	205 (109)	1.41
Average all enterprises		243	303	1.66

Regression analysis was used to relate average annual rainfall (mm) and average length of the growing season (months) to stocking rates (DSE/ha) maintained on the Productivity paddocks. The overall regression analysis and regression coefficients were significant ($P<0.05$). The relationship was:

Carrying capacity (DSE/ha) = -6.25 +2.4Growing season(months) + 0.012Average rainfall(mm)

R^2 0.51, residual standard deviation 5.3

Table 2: The effect of average annual rainfall (mm) and average length of the growing season (months) on carrying capacity (DSE/ha) of Productivity paddocks.

Average rainfall (mm)	Average length of the growing season (months) 5	7	9	11
500	12	14		
700	17	19	21	
900	24	26	28	
1100			31	33

from meat sheep and spring lambing ewes. The poor response of autumn lambing wool sheep to improved pastures is not surprising, given the poor match between feed requirements and pasture growth.

Data for all Productivity paddocks and livestock enterprises were included in this relationship regardless of enterprise profitability and degree of improvement of the pasture. The carrying capacities are, therefore, probably a conservative estimate of true potential if pastures were fully improved and grazed by productive livestock managed to fully utilise the pasture grown. The wide range of environments, soil types, enterprises and pasture conditions included in this analysis reduced the precision of the equation. This "potential carrying capacity", as deduced from average rainfall and length of the growing season, is shown in Table 2.

The influence of GPP on producer attitudes and wider adoption of productive pastures across participating properties was investigated by Trompf (*pers. comm.* 1998). He found that 80% of GPP participants intend to have at least 50% of their properties under productive pastures by 2000. Within 2 years of becoming involved in the program, fertiliser use and stocking rates increased by 93% and 11% on GPP farms whereas there was no change on non GPP farms. The main reason for this rapid change in attitude was that participants saw the benefits of the productive pastures on their own farm under realistic paddock conditions.

Future research

Several important R&D issues were identified during the on-farm evaluation. Overgrazing of Productivity paddocks in autumn and winter led farmers and facilitators involved in GPP to look at alternatives to "continuous stocking", moving to some form of controlled grazing management. On infertile pastures with a low legume content and poor quality herbage, the lower digestibility of the forage reduces the likelihood of overgrazing of the pastures in summer and autumn and land degradation through exposing soil to wind or water. Livestock require supplementary feeding before land sustainability is an issue. With the high quality herbage (high legume content, high digestibility, few low quality species) which is encouraged under productive pasture regimes, good stock performance can be obtained with low herbage mass, leading to overgrazing in late autumn and winter and damage to desirable perennial grasses. In this situation, it may be necessary to destock or provide supplements in autumn even though stock performance is above critical levels.

The impact of higher fertiliser rates on the environment is unclear. Measurements at one site in southern Victoria suggested that there was relatively little movement of P through the soil profile with 80% of applied P still in the top 40 cm, 8% exported in products and 4% transferred to stock camps (McCaskill 1997). However, small amounts of soluble P in runoff water can cause quality problems so research is underway at several sites in Victoria to determine effect of fertiliser rate and grazing management on P movement.

There is also interest in responses to lime and other nutrients, particularly K and nitrogen. While mowing trials have been used to evaluate responses to these products in the past, we now know that these trials grossly underestimate responses in grazed pastures (Cayley *et al.* 1995). Also, the response may have been limited by the low background P fertility in these earlier trials.

Fertiliser responses - what you don't see is what you get!

During GPP and other recent experiments, we have observed superior stock performance on low available herbage in well fertilised paddocks. Over the last 5 years, this issue has been investigated by analysing herbage samples taken from paddocks on the Long Term Phosphate Experiment at Hamilton. This experiment has been running for 20 years and compares from nil to 375 kg/ha/year superphosphate (33 kg/ha P, 41 kg/ha S). In addition, fertiliser test strips were established on a range of the paddocks to allow comparisons of "historical" with "current" fertiliser rates (0-72 kg/ha P) on the nutritive value of herbage.

Experimental details

Herbage samples were collected about 14 days after placing cages at random in paddocks or test strips. Pasture was cut to ground level, avoiding soil contamination, and stored at 4°C until sorted by hand into individual species. All green material (leaves, stem, petiole, seedheads) was retained but senescent herbage was discarded. Perennial ryegrass and subterranean clover were present in all treatments and provided the most complete data set to determine effects of historical and current fertiliser applications on nutritive value. Analyses were undertaken on some other minor pasture species to determine difference in inherent nutritive value and effects of higher fertiliser applications. These species were present only in particular fertiliser x stocking rate environments so samples were bulked across P rates as shown in Table 4.

Individual herbage species samples were dried at 65°C, ground and analysed for crude protein (CP) % and digestible dry matter (DDM) % using Near Infrared Reflectance Spectroscopy. Regression analysis was used to fit exponential functions to the data. Predictive equations used to provide the data for Table 3 were significant ($P<0.05$), the variance accounted for in CP and DDM of subterranean clover and CP and DDM of perennial ryegrass was 85, 85, 83 and 23%, respectively.

Results

Tables 3 and 4 show that DDM% and CP% in most species increased with greater P (S and calcium) applications. The largest increase occurred in subterranean clover with least effect in perennial ryegrass and intermediate responses in other pasture species. A comparison of the influence of historical and current fertiliser rates indicates that despite 2 applications of 30 kg/ha P to previously unfertilised paddocks, DDM was lower than where a high fertiliser rate had been applied for many years.

The reason for this change in nutritive value is unclear though it has been demonstrated in earlier experiments (Ozanne and Howes 1971). Further investigation is required to determine if the causative agent is the P, S or Ca in superphosphate or a combination of all three and the mechanism by which

Table 3: Effects of historical and current fertiliser applications on predicted crude protein and digestible dry matter (DDM) of subterranean clover and perennial ryegrass

Historical P rate (kg/ha/year)	Current P rate (kg/ha/year)	Subterranean clover		Perennial ryegrass	
		Crude protein (%)	DDM (%)	Crude protein (%)	DDM (%)
1	1	21	70	10	71
1	10	21	73	10	71
1	30	23	75	11	71
33	1	27	79	14	73
33	10	27	79	15	73
33	30	27	80	15	73

Table 4: Differences between pasture species and effects of P rate on herbage digestible dry matter %.

Species	Average historical P applied (kg/ha/year)					
	1	4	8	15	23	33
Perennial ryegrass (*Lolium perenne*)	72	73	72	72	72	72
Winter grass (*Poa annua*)		$69^{1,4,8,a}$		71	71	68
Capeweed (*Arthotheca calendula*)		$68^{4,8}$		$66^{15,23}$		67
Barley grass and soft brome (*Hordeum leporinum, Bromus mollis*	70	71	73	74	75	76
Phalaris aquatica		$73^{1,4,8}$			$77^{15,23,33}$	
Vulpia spp.		$66^{1,4,8}$			$70^{15,23,33}$	
Danthonia spp.	$60^{1,4}$		61			
Bent grass (*Agrostis* spp.)	$73^{1,4}$		75			
Onion grass (*Romula rosea*)	60	60	63			
Fog grass (*Holcus lanatus*)		$71^{1,4,8}$			$71^{15,23,33}$	

^{a}Superscripts indicate fertility treatment herbage samples which were combined to provide sufficient material for analysis.

the increased soil fertility changes the cell structure, size or arrangement to improve nutritive value.

Grazing management - back to the future!

Interest in grazing management (GM) has been rekindled by pressure from several directions. The composition of many pastures is sub-standard (Quigley *et al.* 1992) and the Meat Research Corporation sponsored Temperate Pasture Sustainability Key program indicated GM could aid the persistence of perennial grasses (FitzGerald and Lodge 1997). The Grassland's Productivity Program also highlighted the limitations of continuous grazing of high quality pastures (de Fegely 1997). With financial pressure on grazing industries, there has also been a re-evaluation of the role of GM to increase feed supply and allow feed rationing. Many producers are aware that various forms of GM are practised in New Zealand where Hodgson (1990) suggested that meat production is increased by 6-7% compared with continuously stocked systems.

In response, several animal production grazing experiments were established in Victoria. Interim results from the Pastoral and Veterinary Institute, Hamilton project are presented. It must be noted that the experiment is only partially completed and results should be viewed accordingly. Also, statistical analysis of time series pasture composit-ion and persistence data cannot be undertaken until further information are available. However, the consistent pattern of results between this and earlier studies suggest a significant role for GM to improve the productivity and profitability of grazing enterprises.

Experimental details

The experiment started in May 1996 on a site that is marginal for perennial ryegrass with undulating gravelly-loam duplex soils and annual rainfall of 700 mm. Full details of the first 2 years results have been recently reported by Waller *et al.* (1998). Two pastures are used; "Typical pasture" is a degraded perennial ryegrass pasture with 6 kg/ha P and 8 kg/ha S applied annually. Main pasture species are subterranean clover (30%), perennial ryegrass (10%) and silver grass, capeweed, onion grass and fog grass. "Upgraded pasture" was resown in 1989 to perennial ryegrass, cvv. Victorian, Ellett and Kangaroo Valley, phalaris cv. Sirosa and subterranean clover cvv. Trikkala, Larisa and Enfield with 26 kg/ha P and 14 kg/ha S applied annually. The Upgraded pasture is dominated by subterranean clover (35%) and perennial ryegrass (25%) with annual grasses especially barley grass and winter grass. Olsen P was 5 and 11 mg/kg for Typical and Upgraded pastures respectively in spring 1995. Note that the results presented are the mean of these 2 pasture treatments.

Two GM treatments are compared; the control treatment is Continuous Stocking (CS) year round. The second treatment is a 'best bet' rotational grazing system (RG) with four seasonal manage-ment components: A quick summer rotation, of about 5-6 days grazing and 40 days rest, commen-ces as the pasture dries off in December to use some dry feed before quality deteriorates. From early February, a slow rotation (10 to 14 days grazing and about 80 days rest) is used to take herbage mass to 0.8-1.2 t DM/ha by the opening rains. After the opening

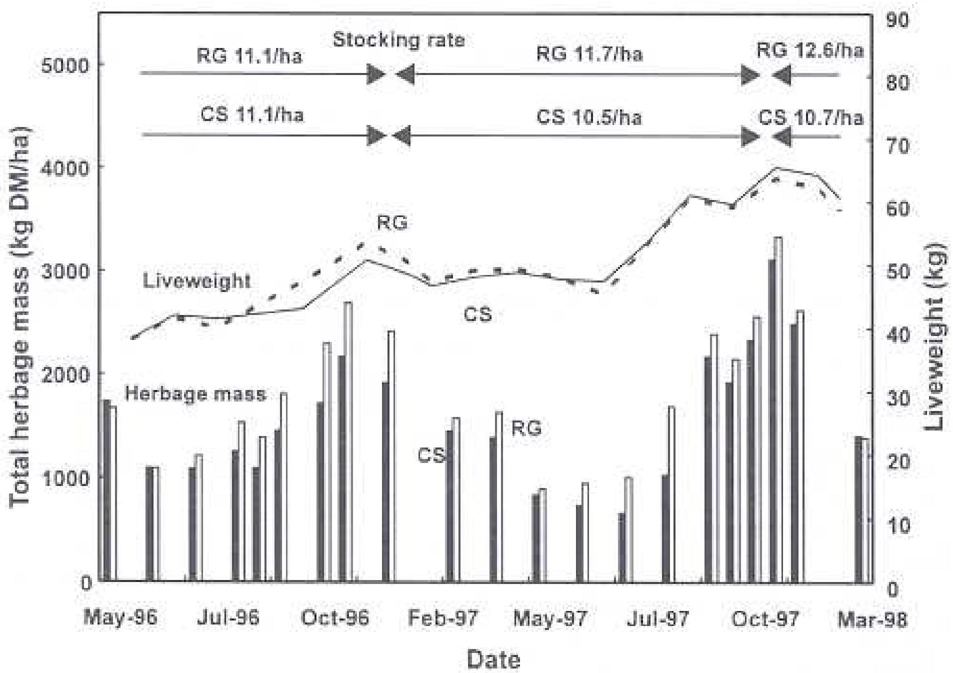

Figure 1: Hamilton experiment- effect of grazing management on total herbage mass (kg DM/ha) and ewe liveweight (kg).

rains, the ewes are deferred on one eighth of the area for about 2 weeks and fed supplements to allow pasture to grow ungrazed. The winter rotation starts with about 3 days grazing per subdivision (30 day rest) and increases to about 9 days grazing, 40-60 days rest. Herbage mass after grazing in winter is around 500 kg DM/ha. Paddocks are continuously grazed from lambing to weaning (September-December).

Plots are grazed by Border Leicester-Merino ewes joined to a terminal sire. Initial stocking rates were based on previous carrying capacity of the paddocks when continuously stocked. Stocking rates were altered in some treatments in January 1996 and 1997 in response to ewe liveweights and herbage mass differences.

Results

Herbage mass, pasture composition, persistence of perennial grasses, animal liveweight and animal productivity (fleece weight, lamb weight) have been measured. Figure 1 shows the herbage mass and liveweight of the sheep over the course of the experiment, data has been combined for both pasture treatments. Herbage mass in the RG treat-ments was greater than in CS paddocks throughout, despite increased stocking rates on the RG treatments in 1997. However, sheep liveweights did not always increase in response to this higher herbage mass; the liveweight of RG sheep was lower than the CS sheep in late spring and summer 1997-98. Lamb weaning weights in 1996 were 33 and 31 kg for RG and CS treatments respectively; 40 and 41 kg for RG and CS treatments in 1997. Weaning weight per ha was therefore 22 and 35 kg higher on the RG than CS treatments, due to the heavier weaning weights in 1996 and higher stocking rates in 1997.

The results from this experiment are similar to earlier findings of Morley *et al.* (1969). There was a consistently higher herbage mass in the RG treatments compared with the CS paddocks, especially in winter. This indicates greater pasture growth (as has been measured directly at Hamilton, 0.6-1.0 t/ha) probably due to the RG pastures reaching the rapid growth phase (Bircham and Hodgson 1983) quicker after the autumn break. This is similar to the findings of Morley *et al.* (1969) where green herbage mass was 1.2-3.2 times greater under RG than CS systems.

Herbage mass in late spring was the same or greater on RG compared to CS systems in our current experiments whereas Morley *et al.* (1969) found reduced herbage mass on a 9 paddock RG system compared to a CS treatment. However, he found no difference in late spring herbage mass between a 3 paddock RG system and a CS treat-ment.

A further similarity between the current experiment and the earlier work is the small increase in animal liveweight and productivity. Liveweights were higher on RG in 1996 but in 1997, both groups were similar despite the increased herbage mass available to the RG ewes. It appears that a decline in pasture quality negated the increase in herbage mass. These results highlight the critical importance of designing a grazing system to use the additional feed grown under RG. Stocking rates must be increased to ensure pastures do not become rank, lose clover content and decline in digestibility. However, it is now apparent that the stocking rate on the RG paddocks in 1997 was still not high enough to utilise the pasture and prevent a decline in quality. If pastures are greater than 1500 kg/ha in late winter, the grazing system is probably out of control and paddocks should be conserved early or stocking rates increased in some way to use the pasture and retain quality. Interim results from three current grazing experiments in Victoria suggest that stocking rates may be increased by 20-30% on RG compared to CS paddocks. However, comparisons of the grazing systems need to be continued to allow more accurate documentation of long-term benefits in carrying capacity and potential detrimental effects on per head productivity.

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