Intensive rotational grazing can improve profitability and environmental outcomes

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Abstract: *Intensive rotational grazing has been adopted by many farmers across southern Australia, to improve financial, environmental and personal elements of farming businesses. Often the shift to an intensive rotational grazing system has been associated with changes to livestock enterprises, stocking rate and phosphorus fertiliser application, making it difficult to determine the specific role of grazing management. An experiment was conducted on native pasture at Panuara near Orange (33˚27'S, 154˚56'E) over a three-year period (2008–10) to investigate how increasing the intensity of grazing management from continuous grazing (one paddock, 1P) to flexible 4- and 20-paddock rotational systems (4P and 20P) influenced profitability and environmental outcomes. Lamb weaning weight decreased with increasing grazing intensity (average weaning weight 1P = 33.7, 4P = 30.6, 20P = 29.9 kg/head), but higher stocking rates were possible with 20P (average stocking rate 2009/2010 1P = 5.2, 4P = 6.0, 20P = 7.2 dry sheep equivalents/ha), due to higher feed-on-offer. Grazing system had limited influence on pasture composition, although ground cover and herbage mass were periodically higher in 20P, particularly in drier autumns (2009 and 2010). Gross margin was higher in the 20P system in 2010 when stocking rates were higher and lambs retained after weaning, but there were no significant differences in other years. Using the average experimental results from 2009 and 2010 there were positive internal rates of return (IRR) in moving from 1P to 4P and 20P systems when infrastructure was in place (18.3 and 23.9% respectively), however, IRR decreased as investment in infrastructure increased.*

Key words: grazing systems, native pastures, merino sheep, Net Present Value (NPV), Internal Rate of Return (IRR), fencing infrastructure investment.

Introduction

Grazing management can simply be defined as 'where or when to move grazing animals' (Sheath and Clark 1996), but this simple description does not describe the flexibility it can provide to a grazing system. Grazing management influences animals, pastures and the soil-water interface. Management of grazing can regulate the quantity and quality of feed-on-offer (FOO) (Waller *et al*. 2001; Morley *et al.* 1969) and be adjusted to meet animal's requirements at specific physiological stages. Grazing management can also be used to manage pasture composition by controlling the timing and intensity of defoliation (Kemp *et al.* 1996), and reducing grazing selectivity of individual species and of areas within the landscape (Sheath and Clark 1996). In addition, controlling grazing can influence soil condition, water infiltration and nutrient cycling (Sheath and Clark 1996). The overall consideration and management of all these factors is aimed at optimising short-term profitability under the constraint of maintaining the resource base over the longer term.

Intensive rotational grazing, also called holistic grazing and time-controlled grazing, is a grazing management system with a high number of paddocks (e.g. 20 or more) stocked at high stocking densities for short periods, followed by long rest periods. In the high rainfall zone (HRZ) of southern Australia intensive rotational grazing has been adopted by many producers. Reasons for adopting intensive rotational grazing are varied, but generally there are profit, environmental and lifestyle considerations. However, the shift to an intensive rotational grazing system has often been associated with changes to livestock enterprises, stocking rate (average and variability) and phosphorus (P) fertiliser application, making it difficult to determine the specific role of grazing management. These other factors can substantially influence profit and environmental outcomes, and an objective appraisal of the grazing management was warranted.

The influence of grazing management was investigated at a systems level in native pasture at Panuara, near Orange in the HRZ of NSW, over a three-year period. The aim was to determine how increasing the intensity of grazing management from continuous grazing (1P) to flexible 4- and 20-paddock rotational systems (4P and 20P) influenced animal production, pasture herbage mass and composition, ground cover and profitability. The Net Present Value (NPV) and Internal Rate of Return (IRR) were also determined for a 100 ha typical farm moving from continuous to rotational grazing, under different starting levels of fencing and water infrastructure.

Methods

Site

The site was located at Panuara 25 km south-west of Orange (33˚27'S, 154˚56'E) with an average annual rainfall of 809 mm. The landscape is undulating and highly variable in aspect, slope, and soil depth. Altitude ranges from 770 to 820 m above sea level, with brown chromosol and kurosol soils (Isbell 1996), derived from siltstone. The pasture was dominated by native perennial grasses that were winter-growing (e.g. *Microlaena stipoides* – Microlaena and *Austrodanthonia* spp. – wallaby grass), with summer growing native perennial grasses (mainly *Bothriochloa macra* – redgrass), naturalised perennial grasses, annual legumes (mainly *Trifolium subterraneum* – subterranean clover) and grasses, and broadleaf weeds also present. The area had never been cultivated and had a moderate superphosphate fertiliser history (~125 kg/ha every three-years).

Treatments

There were three treatments, 1-paddock (1P), 4P and 20P grazing systems, in 3.5 ha plots, which were replicated in three blocks. The 1P system had animals grazing the entire plot continuously.

The 4P system was divided into four equally sized paddocks. Sheep were moved among paddocks based on available feed in relation to the animal requirements and the stage of pasture growth. When animal requirements were higher (e.g. lambing and lactation) animals were moved among paddocks sooner (i.e. pasture were not grazed as heavily), which normally coincided with high pasture growth rates in spring. Sheep were moved into the most suitable paddock determined by FOO, rather than following a set paddock order.

The 20P system was also divided into equally sized paddocks. Sheep were moved among paddocks based on available feed in relation to the animal requirements, pasture growth rate and stage of plant growth. The grazing period generally ranged from one to seven days, averaging four days and rest periods ranged from 30 to 140 days, averaging 70 days. Grazing length was determined by the amount of FOO, with more productive paddocks grazed for longer or more frequently. Paddocks were rotated more quickly when pasture was actively growing in spring, which coincided with higher animal requirements. Paddocks were generally grazed in the same order, but paddocks were sometimes omitted or grazed out-of-order if there was insufficient pasture quality and FOO for the animal requirements, to avoid seed contamination of lambs or to maintain ground cover on ridgelines.

Production system

All treatments had the same production system, animal management and fertiliser. The experiment was stocked with Merino ewes (CentrePlus bloodline), which were joined to White Suffolk rams. Ewes were joined at the beginning of April for one month, shorn in May, and were pregnancy scanned in June. Immediately after scanning, treatments were adjusted to have the same potential number of lambs per ewe. Ewes lambed in September, at the beginning of high pasture growth rates in spring. Lambs were weaned in mid-November (2009) or mid-December (2008 and 2010), and lambs were removed from plots when available feed was not adequate to meet growth rate targets or condition score, or lambs reached an average liveweight of 40–42 kg. In 2008 and 2010, weaned lambs were rotated to another replication in the same treatment and plots were adjusted to have the same potential number of lambs per plot in each replicate.

All treatments had the same stocking rate for the first year of the experiment (5.4 ewes/ha). In February 2009, the stocking rate in individual plots was adjusted proportionally to standing herbage mass of 1.5 t DM (dry matter)/ha. The stocking rate was adjusted at scanning and prior to joining in 2009 and 2010, to maintain >0.8 t DM/ha and >80% ground cover and minimum green FOO targets for the stage of animal production (Bell *et al.* 2006). Ewes in all treatments were confined and fed for eight weeks in June and July 2009 to maintain a ewe condition score >2.5 at lambing.

Superphosphate fertiliser [8.8 % P, 11% sulfur (S)] was applied to 25% of the plot area that was most productive at 250 kg/ha and 125 kg/ha in April 2009 and 2010, respectively.

Measurements

Ewes and lambs (when present on plots) were weighed and body condition scored at 4 to 6 week intervals.

Pastures were visually assessed at 4 to 6 week intervals for total, litter and green herbage mass, plant composition and percentage ground cover using BOTANAL techniques (Tothill *et al.* 1992) in 60 quadrats (0.1 m^2) at fixed locations within each plot. Ten quadrats cut to ground level were used to calibrate visual estimates.

Analyses

Gross margins were prepared for each treatment using costs and prices (excluding lamb price) from NSW DPI budgets in the production year. Store lamb prices were calculated using average prices for weight and condition score grid. The full cost of feeding sheep when off plots was included in the gross margins. The NPV and IRR (Lumby 1991) for each grazing system were calculated for a typical 100 ha farm after 15 years when moving from 1P to 4P and 20P rotational grazing, including both where infrastructure was in place or had to be implemented. Average production results were used from 2009 and 2010, after stocking rates among treatments were adjusted, to form gross margins. The infrastructure to move from 1P to the 4P and 20P rotations was 2000 and 7000 m of fencing, respectively, and three and 12 watering points, respectively. A real discount rate of 5.3% was used to calculate NPV. A second analysis was performed on moving from continuous grazing to 20P rotational grazing, when starting with 20, 14, 10 and 4 existing paddocks. The 14, 10 and 4 existing paddocks were estimated to need 1500, 2500 and 5000 m of electric fencing, and 3, 5 and 12 water points, respectively. Electric fencing was costed at \$5.10/m and watering points at \$3000 each.

All statistical analyses were performed using Genstat 9 (Payne *et al.* 2006), with analysis of variance (ANOVA) used to determine differences between factors and linear mixed models (REML) used for time series analysis.

Results

Animals

Stocking rate was constant among treatments in the first year of the experiment and averaged 9.3 DSE (dry sheep equivalent)/ha across all treatments. Stocking rates in 1P, 4P and 20P in 2009 were 5.1, 5.5 and 6.6 DSE/ha, respectively and in 2010 they were 5.2, 6.4 and 7.7 DSE/ha, respectively. Stocking rate was significantly higher in the 20P system than the 1P and 4P in 2009 and all treatments were significantly different in 2010 (P <0.001).

In 2008, there was no significant difference in lamb numbers between treatments at weaning (Table 1). Lamb weights were greater at weaning in 1P compared with 4P paddock treatment (P <0.05). Individual lamb weight and lamb weight per ha at sale decreased from 20P to 1P and from 1P to

Table 1. Lamb production data for three years from one, four and 20 grazing systems (1P, 4P and 20P). The P value and least significant difference (l.s.d.) for significant treatments are presented.

Year	Measurement	1P	4P	20P	*P*-value	l.s.d.
2008	Lambs weaned/ha	5.6	6.3	5.4	ns	
	Av. weaning wt.	34.1	30.1	32.8	*P* <0.05	2.8
	Av. sale wt.	37.2	35.5	39.7	*P* <0.01	1.2
	Lamb sale wt/ha	209	199.5	223.2	*P* <0.01	6.81
2009	Lambs weaned/ha	5.6	5.6	7.1	ns	
	Av. weaning wt.	31.1	28.6	26.7	ns	
	Av. sale wt.	31.1	28.6	26.7	ns	
	Lamb sale wt/ha	175.8	161.4	187.5	ns	
2010	Lambs weaned/ha	3.9	5	5.6	*P* <0.05	1.3
	Av. weaning wt.	35.9	33.1	30.3	*P* <0.01	2.1
	Av. sale wt.	39.2	38.2	36.4	ns	
	Lamb sale wt/ha	149.4	189.2	218.4	*P* <0.01	24.49

4P (P <0.01). In 2009, lambs were sold at weaning and there was no significant difference in lamb number, weight at weaning, and lamb weight/ha. In 2010, 20P weaned more lambs per ha than 1P (P <0.05). Weaning weight was decreased from 1P to 4P, and from 4P to 20P (P <0.01), but sale weight was not significantly different as sale time was staggered as animals reached target weight. Lamb production/ha increased from the 1P to 4P and from 4P to 20P (P <0.01).

Pastures

Pasture composition (species averaging >1% of the herbage mass) varied with season and to a lesser extent with grazing system (Figure 1). Major species found were *Austrodanthonia* spp. (wallaby grass), *M. stipoides* (Microlaena), *Elymus scaber* (common wheat grass), *Austrostipa* spp. (corkscrew grass), *B. macra* (redgrass), *Poa bulbosa, Holcus lanatus* (Yorkshire fog), *Lolium rigidum* (annual ryegrass), *T. subterraneum* (subterranean clover), *Hypochaeris radicta* (catsear) and *Acetosella vulgaris* (sorrel).

Microlaena was initially greater in 20P than 4P and 1P (1313 v 835 kg DM/ha, P < 0.05). This difference was significant again regularly from August 2008 to October 2009 (average 651 v 354 kg DM/ha, P < 0.05) and in March 2011 the 20P was significantly greater than 4P (2590 v 1416 kg DM/ha, P < 0.05). Common wheatgrass was greater in 20P than both 1P and 4P periodically from September 2008 (average 101 v 36 kg DM/ha, P < 0.05). Redgrass was greater in 4P than 20P in June (278 v 90 kg DM/ha, P < 0.05) and November (173 v 21 kg DM/ha, P < 0.05) 2008 and January 2010 (160 v 25 kg DM/ha, P <0.05) and 1P was also greater than 20P in the November 2008 (111 v 21 kg DM/ha, P <0.05). In June 2009, there was more *P. bulbosa* in 20P than both 1P and 4P (117 v 82 kg DM/ha, P < 0.05). At the peak of production, in spring

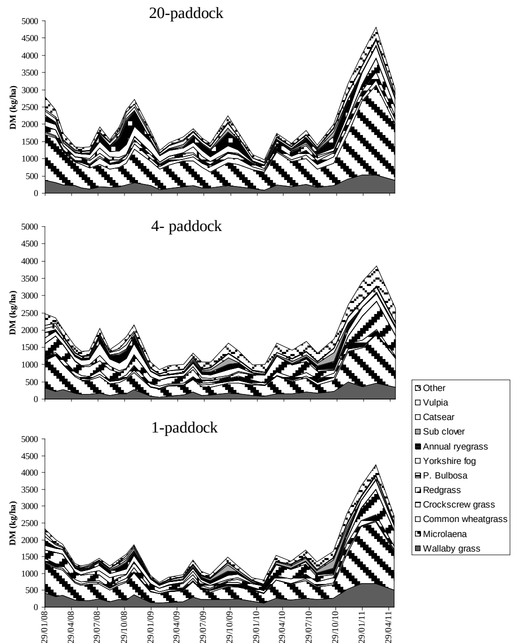

Figure 1. Herbage mass (kg DM/ha) of the major species for the 1-, 4- and 20-paddock grazing systems.

each year, annual ryegrass increased from 1P to 4P to 20P (average 132 v 198 v 370, *P* <0.05). In August 2008, there was less subterranean clover in 20P than 4P and 1P treatments (5 v 21 kg DM/ha, *P* <0.05). Later in spring and in following years this difference was evident, but not significant.

Grazing treatment had a significant influence on ground cover (Figure 2), with 20P on average having higher levels than 1P and 4P (*P* <0.01). The difference was greatest in summer and autumn 2009 (20P = 91%, 1P and 4P = 82%, *P* <0.001) and 2010 (20P = 88%, 1P and 4 = 82%. *P* <0.001).

Gross margin

There was no significant difference in gross margins/ha between grazing systems in 2008 or 2009, with only \$18/ha and \$36/ha between the highest and lowest treatments, respectively (Table 2). In 2010, the 20P treatment resulted in a \$210 higher gross margin/ha than 1P, and a \$96/ha higher gross margin than 4P (*P* <0.01).

Return on investment

Using the experimental results from 2009 and 2010 for a 100 ha typical farm, moving from a continuous grazing to a 4P or 20P grazing system, without investment in infrastructure had a NPV (IRR in parenthesis) of \$9293 (18.3%) and \$41627 (23.9%), respectively. When the cost of all infrastructure was included the NPV was substantially lower at −\$7370 (2.2%) and −\$20599 (2.9%) for the 4P and 20P, respectively, with neither investment being viable. As level of existing infrastructure clearly influences the benefits of moving to a rotational grazing system, the level of initial infrastructure in the 20P system was investigated further. The NPV (and IRR) of moving from continuously grazing to a 20P rotational grazing, starting with 20, 14, 10 and four paddock infrastructure was

Table 2. Gross margin/ha, ewe and DSE from one, four and 20 paddock grazing systems (1P, 4P, 20P, respectively)from 2008 to 2010. Different letters in subscript denote significant differences (*P* <0.05), where there are no letters there are no significant differences.

Year	System	GM/\$ ha	GM/\$ ewe	GM/\$ DSE
2008	20P	377.89	69.96	38.33
	4P	372.88	68.51	37.42
	1P	359.64	66.58	36.64
2009	20P	233.42	41.96	28.10
	4P	197.54	41.50	29.28
	1P	238.77	56.18	38.57
2010	20P	581.23_a	127.04	75.37
	4P	484.82_b	138.50	75.96
	1P	371.00_c	113.68	69.54

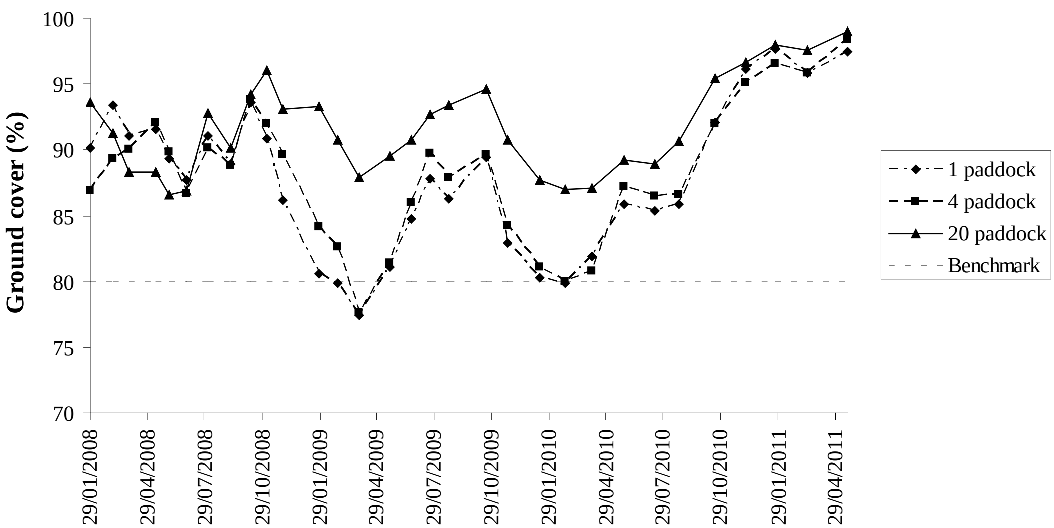

Figure 2. Average ground cover (%) for 1P, 4P and 20P treatments at Panuara. A benchmark of 80% was set for the minimum average groundcover for individual plots.

$41627 (23.9%), $27177 (13.1%), $17544 (9.6%) and –$11747 (3.9%), respectively (Table 3). However, with a more effective infrastructure design, using a wagon wheel design with four paddocks, reduced the initial investment in watering points from 12 to three, even though fencing length increased. The overall investment cost decreased and had a NPV of $4356 (6.4%), which made the development of a 20P system from a 4P infrastructure a viable investment.

Discussion

This experiment showed a trade-off between per head production, measured by lamb weaning and sale weight, and per ha production (kg lamb/ha) as grazing intensity increased. Per head production was highest, with continuous grazing (e.g. average weaning weight 1P = 33.7, 4P = 30.6, 20P = 29.9 kg/head) but there was lower FOO and stocking rates were lower (average stocking rate 2009/2010 1P = 5.2, 4P = 6.0, 20P = 7.2 DSE/ha). These differences in stocking rates were of similar magnitude to those found by Warn *et al.* (2002) for similar grazing treatments with Merino wethers in phalaris pastures. In 2008 and 2010, 20P had the highest lamb production/ha. In 2008, treatments had the same stocking rate, but lambs were retained for longer on 20P because of higher FOO. In 2010, the higher production on 20P was due to a higher stocking rate. The lower per head production as grazing intensity increased was most likely due to grazing management restricting animals and forcing them to consume pasture species or plant parts of a lower quality. Continuous grazing allowed animals to be more selective in diet selection and areas to be continually defoliated, which resulted in higher quality forage (Cox, unpublished) due to a positive feedback caused by grazing (McNaughton 1984). While stocking rates were objectively determined, seasonal conditions meant higher stocking rates could have been run in all grazing systems in 2010 due to above average rainfall and this would have influenced production/ha.

There was little consistent change in species composition associated with grazing management, particularly for perennial species. There were some differences among treatments from the beginning of the experiment that were maintained (e.g. Microlaena) and others that were seasonal (e.g. higher common wheatgrass and *P. bulbosa* in 20P). Annual species differences were more consistent with more annual ryegrass in spring as grazing intensity increased. Annual ryegrass was observed to be selectively grazed in the continuous grazing treatment preventing it from reaching the 20P level. In 2008, there was less subterranean clover in 20P, but this trend did not continue at a significant level. Herbage mass and at times ground cover were improved with increasing intensity of grazing management. Warn *et al.* (2002) also found that ground cover in autumn was higher in 20P and 4P plant-based flexible rotations compared with continuous grazing. While other environmental variables were monitored in this experiment (e.g. perennial plant frequency, soil water, infiltration and sediment runoff) none showed differences due to grazing treatment (data not presented).

There was little difference in profitability in 2008 since all treatments had the same stocking rate (5.4 ewes/ha). In 2009, stocking rates were adjusted based on FOO which gave an opportunity for a larger difference in profitability among systems. However, there were still no significant differences among treatments. The higher stocking rate in 20P was offset by lower lamb growth rates, so little difference was achieved in this season when lambs were

Table 3. Relationship between Net Present Value (NPV) and Internal Rate of Return (IRR) with initial paddock number when moving from continuous grazing to 20P rotational grazing.

System change	NPV ($)	IRR (%)
20-paddocks continuously grazed to 20P rotation	41627	23.9
14-paddocks continuously grazed to 20P rotation	27177	13.1
10-paddocks continuously grazed to 20P rotation	17544	9.6
4-paddocks continuously grazed to 20P rotation	–11747	3.9
4-paddocks continuously grazed to 20P rotation – wagon wheel	4356	6.4

weaned and sold early (November). In 2010, the 20P system had a higher gross margin, due to a higher stocking rate. While the average weaning weight in 20P was lower, lambs were turned-off the 1P system sooner, because they attained target weights earlier.

There were viable IRRs when moving from continuous to rotational grazing when no expenditure on infrastructure was required (4P = 18.3% and 20P = 23.9%). However, when investment in infrastructure was required the IRR was reduced (e.g. 13.1 and 9.6% when moving from 14 and 10 paddocks continuous grazing to 20P rotational). Although these levels of return are competitive against capital market returns, any initial systems with lower numbers of paddocks did not produce viable returns (e.g. 3.9 and 2.9% when moving from 4- and 1-paddock continuous grazing to 20P rotational). However, if rotational grazing was implemented without additional infrastructure from 4- to 14-paddocks, then IRRs would be between 18.3 and 23.9%. Care should be taken interpreting these results as this analysis did not take into account variability in results due to season, changes in fixed costs and in slow changing variables, such as pasture composition and soil nutrient cycling. Also, tactical paddock subdivision to allow more efficient use of the landscape may have greater benefits than described in this analysis, as well as moving to rotational grazing if continuous grazing had been implemented without flexible management to preserve pastures. Never-the-less the concept shows implementing grazing management with minimal subdivision can improve business returns.

Conclusions

Increasing the intensity of grazing management can improve business profitability provided there is little investment in infrastructure required, stocking rate is increased and the season allows lambs to be retained beyond weaning. While there was an indication that environmental variables could be improved with increasing intensity of grazing management, the minimum herbage mass (0.8 t DM/ha) and ground cover (80%) levels and flexible stocking rate prevented widespread pasture degradation in any system. Moreover, the experiment had insufficient time to adequately assess slow changing variables, such as pasture composition and soil nutrient cycling.

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