Development options in *Heteropogon contortus* grasslands in south-east Queensland: tree killing, legume oversowing and pasture replacement.
2. Animal production

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Abstract

This paper reports levels of animal production from various development options in a black speargrass (*Heteropogon contortus*) community in south-east Queensland. The study commenced in 1972 and measured the effects of tree killing, siratro oversowing and pasture replacement at a range of stocking rates. Summer rainfall was mostly above average during Phase I (1972–77), and mostly below average in Phase II (1979–86).

During Phase I, killing trees increased liveweight gain (LWG) from 12 kg/ha to 22 kg/ha at 0.18 hd/ha, and to 40 kg/ha at 0.41 hd/ha, with corresponding LWG/hd of 67, 121 and 97 kg. Oversowing with siratro (*Macroptilium atropurpureum* cv. Siratro) + Mo superphosphate increased LWG to 60 kg/ha (161 kg/hd) at 0.41 hd/ha and 104 kg/ha (139 kg/hd) at 0.75 hd/ha. In the second phase, LWG at 0.75 hd/ha remained almost unchanged at 102 kg/ha. In Phase I, introducing buffel grass (*Cenchrus ciliaris* cv. Biloela) and siratro (+ Mo superphosphate) as a fully sown pasture increased LWG to 123 kg/ha (164 kg/hd) at an average stocking rate of 0.74 hd/ha, compared with 109 kg/ha (145 kg/hd) for the native-siratro pasture averaged over the same stocking rates. At 1.11 hd/ha the buffel-siratro pasture produced 177 kg/ha LWG. However, in the drier second phase, this decreased to 146 kg/ha at the same stocking rate.

The development options of oversowing siratro into cleared native pasture and establishing a fully sown grass-siratro pasture led to 3- and 4-fold increases in LWG/ha, respectively, over that from cleared native pasture. However, the higher stocking rates imposed are now considered unsustainable and at more sustainable rates the increases in LWG/ha were 2- and 3-fold, with similar increases in gross income.

Yield of green pasture in autumn explained 50% of the variation in LWG in the buffel-siratro pasture (P<0.01), with no correlation between LWG and green yield for the other 3 pasture types. Similar results were found when LWG was related to % utilisation.

The implications of treatment, stocking rate, green yield, % utilisation and the different climate periods are discussed in relation to sustainable stocking rates, animal production and economic viability of the development options. The stocking rates considered sustainable are considerably lower than the calculated 'optimum' rate using the linear stocking rate model, and the inapplicability of the linear stocking rate model for use in the rangelands is also discussed.

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Introduction

Animal performance in the black speargrass (*Heteropogon contortus*) region of subtropical Queensland is limited by low quality herbage during the dry season. The protein content of native pastures can drop to <5% and even as low as 1% (Christian and Shaw 1951; Shaw and Bisset 1955). As a result, speargrass country was used mostly for cattle breeding enterprises and rarely for fattening. While it was known that substantial benefits in animal production could be achieved by the introduction of a vigorous legume into native speargrass pasture (Shaw 1961; Shaw and Mannetje 1970), those studies had been carried out using *Stylosanthes humilis*. However, this species was not well adapted to the subtropics. This led to the use of the twining legume siratro (*Macroptilium atropurpureum* cv. Siratro) as a then largely untried alternative, particularly in native pastures.

At the time of formulating this experiment (around 1970), several strategies for pasture development were being suggested to overcome the limitations of speargrass pastures: clearing of trees; oversowing a legume into native pastures; and replacing native pastures with sown grass plus a legume. Tothill *et al.* (2008) report the impacts of these developments on pasture production and composition. Killing trees doubled pasture production, with little change in composition, while oversowing siratro dramatically changed the composition. Highest pasture yields were obtained from a fully sown replacement pasture.

While much of this land type has already been cleared and the experiment was conducted some 20–30 years ago, most of the findings are still highly relevant. Some 30–50% of producers in northern Australia are still using a combination of native and introduced pastures (Bortolussi *et al.* 2005b) for beef production, and most see a future for introduced pasture plants (McDonald and Clements 1999). This paper presents the impact of these pasture developments on animal production at a range of stocking rates.

Materials and methods

Site

The 270 ha experiment was located on the former CSIRO Narayen Research Station (25° 41′ S, 150° 52′ E) in south-east Queensland. For a detailed description of the vegetation and soils of the experimental site see Tothill *et al*. (2008).

Average annual rainfall of approximately 700 mm is summer-dominant (December–March). Low rainfall and low minimum temperatures (including frosts) severely reduce plant growth in winter. Detailed meteorological information is available in Cook and Russell (1983).

Treatments

The experiment was established during 1971–72. In the initial phase (1972–77), there were 24 paddocks representing 12 treatments with 2 replications (Table 1). The experiment was a completely randomised design of 4 main treatments and 7, varyingly allocated, stocking rate sub-treatments. Phase II (1979–1986) comprised the main treatments from Phase I, but at a reduced number of stocking rates, and was augmented with new treatments, which will be described elsewhere.

Phases I and II comprised the main treatments of:

C — native pasture, natural woodland with trees intact (Control),

N — native pasture with trees killed,

NS — native pasture with trees killed and oversown with siratro and P fertiliser,

BS — trees cleared, seed-bed cultivated, fully sown buffel grass (*Cenchrus ciliaris*) + siratro replacement pasture and P fertiliser.

Further details of the main treatments are given in Tothill *et al*. (2008). In the NS and BS treatments, 200 kg/ha of single superphosphate (9.6% P) plus molybdenum at 300 g per ha was applied at sowing of introduced species and 100 kg/ha of triple superphosphate (19% P) was applied biennially. In Phase II, 100 kg/ha triple superphosphate was applied at 3-year intervals.

Stocking rates

Stocking rates on native pastures were based on commercial rates for black speargrass pastures in the area (Table 1). For the treatments containing siratro, the rates were based on levels indicated by the initial trial experiences of Mannetje (Mannetje and Butler 1991) at Narayen. All the treatments were set-stocked with Hereford and Africander cross steers in Phase I and mostly with

Table 1. Main treatments and stocking rates for Phase I (1972–77) and Phase II (1979–86) of the experiment.

Stocking rate (ha/hd)	5.7	3.4	2.4	1.7	1.4	1.1	0.9
(hd/ha)	0.18	0.29	0.41	0.58	0.75	0.93	1.11
Phase I							
Control (C)	$C_{0.18}$						
Native, trees killed (N)	$N_{0.18}$	$N_{0.29}$	$N_{0.41}$				
Native, trees killed, + siratro + P (NS)			$NS_{0.41}$	$NS_{0.58}$	$NS_{0.75}$	$NS_{0.93}$	
Buffel-siratro + P, trees cleared (BS)				$BS_{0.58}$	$BS_{0.75}$	$BS_{0.93}$	$BS_{1.11}$
Phase II							
Control (C)	$C_{0.18}$						
Native, trees killed (N)			$N_{0.41}$				
Native, trees killed, + siratro + P (NS)					$NS_{0.75}$		$NS_{1.11}$
Buffel-siratro + P, trees cleared (BS)							$BS_{1.11}$

Belmont Red steers in Phase II. Animals were introduced annually as weaners at 6–8 months of age (170–220 kg) and remained on the trial for 2 years, with half the animals in each paddock changing each year. Paddock sizes varied with treatment with 4 animals per paddock.

Measurements

During Phase I, animals were weighed at 28-day intervals after an overnight fast. During Phase II, based on the previous 5 years of information, animals were weighed on 5 strategic occasions per year. These were occasions of significant change, *i.e.*, late dry season-early wet season and late wet season-early dry season. Animal intake was derived from animal liveweight and rate of gain using the formula of Minson and McDonald (1987). Utilisation was calculated using the estimated annual animal intake as a percentage of annual growth, taken as the autumn green yield.

Over Phase I, animals were evaluated following slaughter at the abattoir for commercial grade, cold dressed weight and back fat at the twelfth rib. Dressing percentages were calculated on the basis of dressed weight and final fasted live weight.

Estimates of pasture yield and composition were done 8 times a year during Phase I, and once a year at the end of the peak growth period (March–April) during Phase II. Details of pasture sampling methods are given in Tothill *et al.* (2008).

Statistical analyses

Animal liveweight gains, per head and per ha, were analysed using analysis of variance on an annual and seasonal basis. Analyses of carcase weight and dressing percentage were adjusted using the initial live weight as a covariant. Since each of the animals remained on the experiment for 2 years, and these were split into 2 subsets of 2 animals, which overlapped each other in time by 1 year, the analyses were based on the animal subsets for 1972–74, 1973–75, 1974–76, 1975–77 and averaged over 1972–77. All analyses of variance were carried out using GENSTAT (C) 1980 Lawes Agricultural Trust (Rothamstead Experimental Station). Regression relationships were derived using the analysis tool in Excel ©.

Results

Climate

Detailed rainfall and temperature information for the experimental period are given in Tothill *et al*. (2008). In broad terms, Phase I, with 3 out of 5 years of near or above median spring-summer rainfall (488 mm) was wetter than Phase II with only 3 out of 8 years with above median annual or spring-summer rainfall. In Phase II, 5 of the 8 years had spring-summer rainfall below decile 3 (401 mm). However, when compared with the more recent 30-year period (1969–98), the experimental period 1979–86 was closer to normal with 4 out of 8 years below median annual (623 mm) and 5 years below median spring-summer (414 mm) rainfall, and only 2 spring-summers below decile 3 (382 mm).

Main treatments — the 4 land use systems

The main effects for 4 main land use systems (C, N, NS and BS) for Phases I and II are given in Table 2. Values for both production per head and production per hectare are presented, averaged over stocking rates.

Production per head. Throughout Phase I, liveweight gains (LWG) generally increased significantly ($P<0.01$) with level of development with $C<N<NS$, BS, except in the first year when $C<N$, $NS<BS$. In the first part of Phase II, 1979–83, LWG from all developed treatments exceeded those from the control ($C<N$, NS, BS), but from 1984–86, after the 1982–83 drought, there was no significant difference ($P>0.05$) between treatments. Mean LWG on the control was 39% higher in Phase II than in Phase I, while LWG on NS and BS treatments declined by 13% and 20%, respectively. Seasonal differences between some treatments occurred in almost all years from 1972-83 (Figures 1 and 2). However, from 1984-86 there were no differences annually or seasonally.

Production per hectare. In almost all years of Phase I, 1972–77, LWG/ha increased significantly ($P<0.01$) with increasing level of development (Table 2). However, during the years 1979–86, the effects were not so pronounced. In most years, LWGs/ha from the NS and BS treatments were not significantly different ($P>0.05$), but gains were always significantly greater ($P<0.01$) than those from the N and C treatments. Seasonal differences between treatments occurred

Table 2. Main treatment effects on annual liveweight gains of steers averaged over stocking rates for years 1972–86. C: native pasture with trees; N: native pasture, trees killed; NS: native pasture, trees killed + oversown with siratro + P; BS: sown buffel-siratro pasture + P, trees cleared. Within years, values followed by different letters (a,b,c for kg/ha and x,y,z for kg/hd) differ (P<0.01).

Treatment	C	N	NS	BS	C	N	NS	BS
No. animals 1972–77	8	24	32	32	8	24	32	32
No. animals 1978–86	8	8	16	8	8	8	16	8
Years	(kg/ha)				(kg/hd)			
1972–73	14.3d	34.9c	88.3b	146.7a	79.5z	119.8y	133.4y	176.4x
1973–74	11.7d	26.8c	95.0b	137.8a	64.9z	93.0y	145.4x	165.3x
1974–75	12.7d	32.3c	104.4b	122.8a	70.8z	114.6y	157.0x	147.4x
1975–76	11.7d	31.3c	105.6b	140.1a	65.1z	111.7y	161.3x	173.4x
1976–77	9.6d	31.3c	97.7b	126.5a	53.1z	110.6y	149.1x	150.0x
Mean	12.0d	31.3c	98.1b	134.8a	66.7z	109.9y	149.2x	162.5x
1978–79	12.1c	54.7b	134.5a	164.6a	67.3y	133.4x	138.3x	148.3x
1979–80	16.2c	60.5b	140.7a	149.7a	89.8y	147.6x	149.8x	134.9x
1980–81	20.2d	55.5c	147.7b	188.1a	112.0z	135.3y	158.2xy	169.5x
1981–82	19.5d	51.1c	136.2b	180.4a	108.4z	124.8yz	142.5xy	162.5x
1982–83	13.1b	52.1b	124.6a	151.8a	72.8y	127.0x	131.5x	136.8x
1983–84	21.6b	45.4b	114.3a	136.7a	119.9	110.8	121.7	123.1
1984–85	16.3b	40.3b	100.1a	113.9a	90.4	98.4	106.3	98.8
1985–86	14.6b	30.1b	88.9a	85.0a	81.0	73.4	95.0	73.6
Mean	16.7c	48.7b	123.4a	146.3a	92.7z	115.1y	130.4x	130.9x

Stocking rates from which means are derived (hd/ha):
1972–77 C = 0.18; N = 0.18, 0.29, 0.41; NS = 0.41, 0.58, 0.75, 0.93; BS = 0.58, 0.75, 0.93, 1.1.
1978–86 C = 0.18; N = 0.41; NS = 0.75, 1.1; BS = 1.1.

throughout all years (Figures 1 and 2) but in a somewhat different pattern from the LWG/head responses. Winter differences occurred in the first 3 years only (1972, 1973 and 1974). Interestingly, in the winter of 1974, weight loss was greatest in the BS treatment (Figure 1). Differences in LWG/ha were apparent in all summers and 4 out of 8 autumns in Phase II.

Stocking rate effects

LWG/hd generally declined as stocking rate increased in all years (Figures 3 and 4), while LWG/ha increased; however, the decline in LWG/hd was not always linear. Averaged over Phase I, stocking rate had the least effect on the improved pastures with decreases in LWG/hd of approximately 26, 44 and 120 kg per unit increase in stocking rate for the BS, NS and N treatments, respectively. The linear model predicts maximum LWG/ha at stocking rates of 3.6, 2.0 and 0.6 hd/ha for the BS, NS and N treatments, respectively, all of which greatly exceed the rates used in this trial.

Seasonal effects

In general, animals lost weight in winter and gained weight in spring, summer and autumn (Figure 5). While the greatest gains were in summer, this period showed the least difference between treatments. There was an additive effect of seasonal responses to different developments. Killing trees increased the spring LWG over the control; oversowing siratro plus fertiliser reduced winter weight loss and increased autumn gain over killing trees; and the fully sown pasture plus fertiliser increased spring gain over the oversown pasture. For all treatments, the biggest differences in LWG/hd between stocking rates were in winter, with the least differences in summer (Figure 5).

The effect of killing trees on native pasture

In Phase I, comparing C and N at the same stocking rate of 0.18 hd/ha ($C_{0.18}$, $N_{0.18}$), killing trees significantly (P<0.01) increased LWG/hd, but at stocking rates likely to be at a more comparable grazing potential, 0.18 ($C_{0.18}$) and 0.41 ($N_{0.41}$) hd/ha, differences were not significant (Table 3). Responses were similar in 1978–86 but production levels were higher. The results indicate that tree removal doubled LWG/hd and, at the increased stocking rate, trebled LWG/ha.

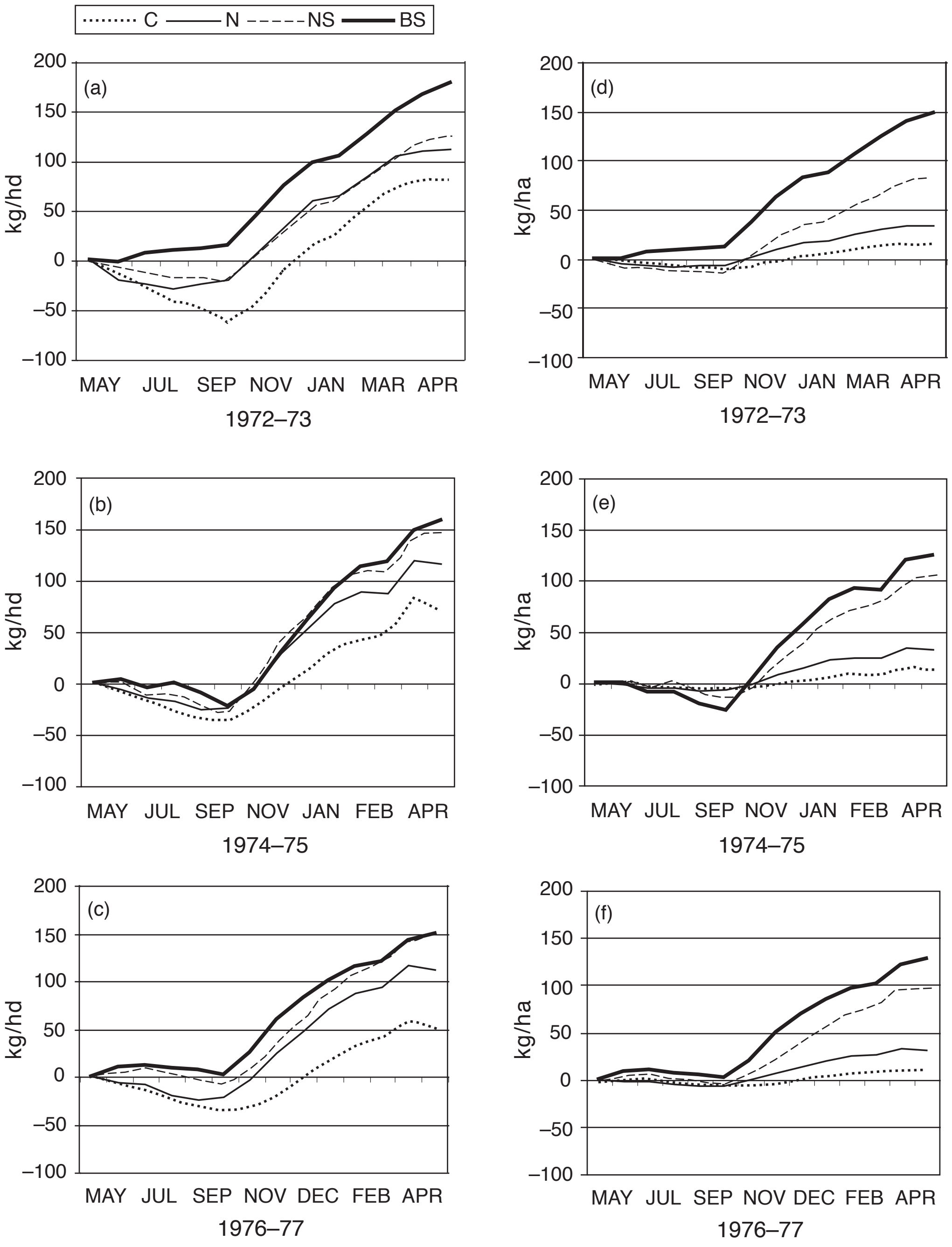


Figure 1. Cumulative liveweight change of steers, averaged over stocking rates, for 1972–73, 1974–75 and 1976–77, in kg per hectare and kg per head. C = native pasture Control (······); N = native pasture with trees killed (——); NS = native pasture with trees killed and siratro sown + Mo superphosphate (−−−); BS = trees removed and buffel grass-siratro pasture sown + Mo superphosphate (▬▬). The years presented were selected as representative of the variation between years.

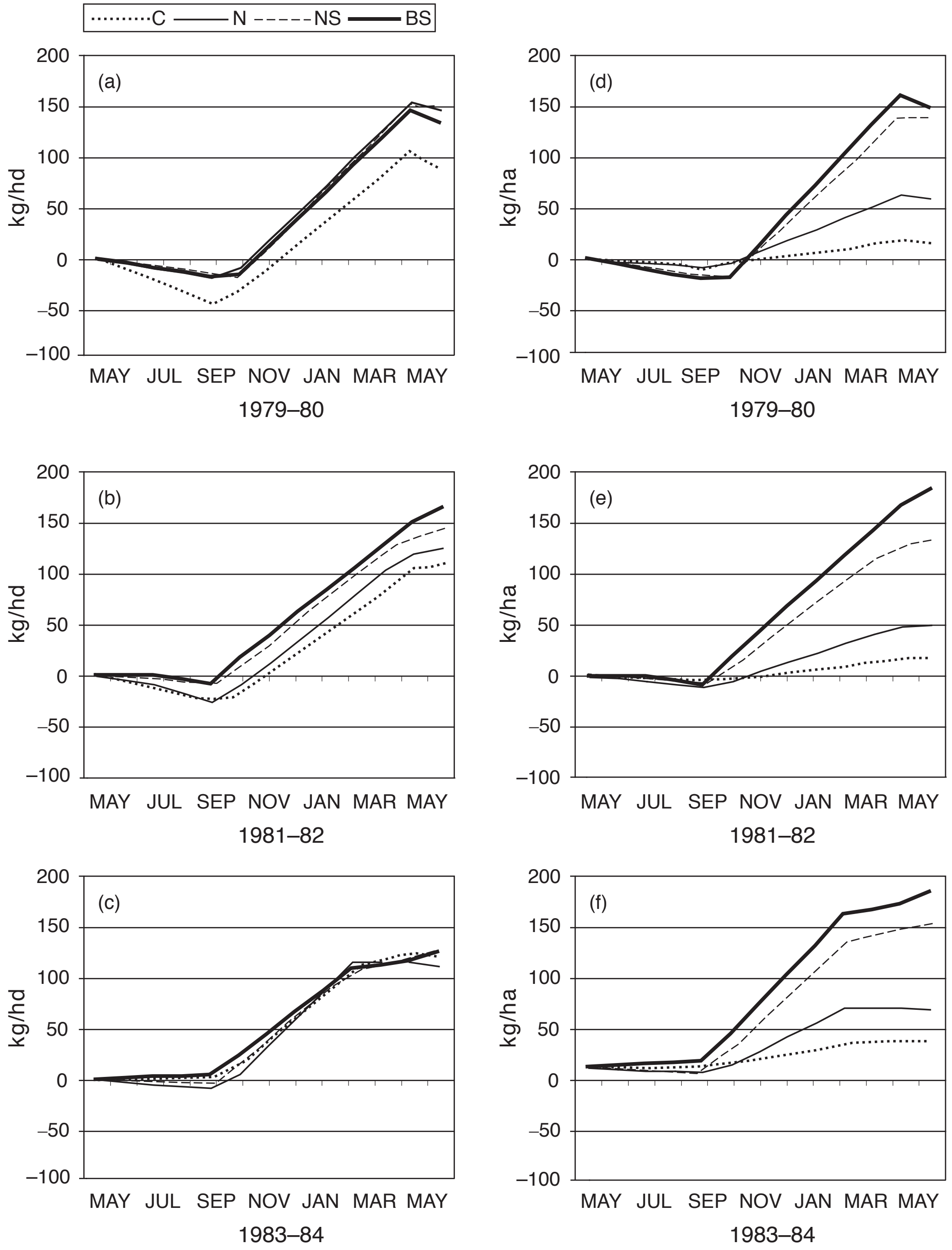


Figure 2. Cumulative liveweight change of steers, averaged over stocking rates, for 1979–80, 1981–82 and 1983–84, measured at 5 strategic intervals per year, in kg per hectare and kg per head. C = native pasture Control (······); N = native pasture with trees killed (——); NS = native pasture with trees killed and siratro sown + Mo superphosphate (– – –); BS = trees removed and buffel grass-siratro pasture sown + Mo superphosphate (▬▬). The years presented were selected as representative of the variation between years.

Table 3. Effect of trees on liveweight gains of steers on native black speargrass pastures for 1972–86. C: native pasture with trees; N: native pasture, trees killed. Subscripts indicate stocking rates in hd/ha. Within years, values followed by different letters (a,b,c for kg/ha and x,y,z for kg/hd) differ (P<0.01).

Treatment	$C_{0.18}$	$N_{0.18}$	$N_{0.41}$	$C_{0.18}$	$N_{0.18}$	$N_{0.41}$
No. animals	8	8	8	8	8	8
Years		(kg/ha)			(kg/hd)	
1972–73	14.3c	22.3b	48.6a	79.5y	124.1x	118.6x
1973–74	11.7b	17.7ab	35.1a	64.9	98.2	85.5
1974–75	12.7b	23.6ab	39.5a	70.8y	131.0x	96.5y
1975–76	11.7b	22.8ab	36.1a	65.1y	126.6x	88.1xy
1976–77	9.6b	22.8b	39.3a	53.1z	126.5x	95.9y
Mean	12.0c	21.8b	39.7a	66.7y	121.2x	96.9y
1978–79	12.1b		54.7a	67.3y		133.4x
1979–80	16.2b		60.5a	89.8y		147.6x
1980–81	20.2b		55.5a	112.0		135.3
1981–82	19.5b		51.1a	108.4		124.8
1982–83	13.1b		52.1a	72.8y		127.0x
1983–84	21.6b		45.4a	119.9		110.8
1984–85	16.3		40.3	90.4		98.4
1985–86	14.6		30.1	81.0		73.4
Mean	16.7b		48.7a	92.7		118.8

The effect of oversowing siratro into native pasture without trees

In this analysis, the N and NS treatments are compared at the corresponding stocking rate of 0.41 hd/ha in Phase I ($N_{0.41}$, $NS_{0.41}$), and at 0.41 and 0.75 hd/ha in Phases I and II ($N_{0.41}$, $NS_{0.75}$).

During Phase I, LWG/hd was significantly higher (P<0.01) from native pastures with siratro than without (Table 4) in most years. In Phase II, LWG/hd from $N_{0.41}$ pastures was considerably better than in Phase I, but in only 1 year (1980–81) was there a significant difference between treatments $N_{0.41}$ and $NS_{0.75}$ (Table 4).

At 0.41 hd/ha, introducing siratro significantly (P<0.01) increased LWG/ha every year except the first. Increasing stocking rate to 0.75 hd/ha on the NS treatment further increased (P<0.01) LWG/ha in every year (Table 4). Oversowing siratro increased LWG/ha by 50% at the same stocking rate in Phase I, but at the increased stocking rate, siratro increased LWG/ha by 160% in Phase I and 100% in Phase II.

Comparison of oversown native pasture with replacement sown pasture

Common stocking rates for these treatments were 0.58, 0.75 and 0.93 hd/ha over Phase I, while in Phase II there was only the 1 common stocking rate of 1.11 hd/ha.

In a similar way to the main effects, BS exceeded NS significantly (P<0.01) in both LWG per head and per hectare in the first 2 years but, thereafter, there were no significant differences during Phase I (Table 5). As might be expected, there were always differences between stocking rates in LWG/ha, but not LWG/hd, within both NS and BS treatments (data not shown). In Phase II, there were no consistent differences in LWG/hd between $NS_{0.75}$ and $NS_{1.11}$ and $BS_{1.11}$, but LWG/ha was significantly (P<0.01) less in $NS_{0.75}$ than $NS_{1.11}$ in 5 years out of 8, and less than BS in 4 years out of 8.

Animal carcase studies

The results closely follow the effects for animal LWG from the main treatments.

Effect of killing trees on native pasture. There was a significant (P<0.01) increase in carcase weight as a result of removing the trees ($C_{0.18}$ *vs* $N_{0.18}$) in all periods. Depth of back fat and dressing percentage were always higher in $N_{0.18}$ but differences were not always significant. Over the 4 periods, more than 90% of carcases from the $C_{0.18}$ treatment rated Grade 3 or lower, whereas nearly 70% of carcases from the $N_{0.18}$ treatment rated Grade 2, and 25% rated Grade 1. When the 2 stocking rates for the tree killing ($N_{0.18}$ and $N_{0.41}$) were compared, carcase weight and dressing percentage were lower at the higher stocking rate in

Table 4. Effect of introducing siratro into black speargrass pasture on annual liveweight gains of steers for 1972–86. N: native pasture, trees killed; NS: native pasture, trees killed + oversown with siratro + P fertiliser. Subscripts indicate stocking rates in hd/ha. Within years, values followed by different letters (a,b,c for kg/ha and x,y,z for kg/hd) differ (P<0.01).

Treatment	$N_{0.41}$	$NS_{0.41}$	$NS_{0.75}$	$N_{0.41}$	$NS_{0.41}$	$NS_{0.75}$
No. animals	8	8	8	8	8	8
Years		(kg/ha)			(kg/hd)	
1972–73	48.6b	59.0b	88.5a	118.6	144.0	118.0
1973–74	35.1c	66.6b	96.9a	85.5y	162.4x	129.3xy
1974–75	39.5c	63.8b	113.1a	96.5y	155.5x	150.8x
1975–76	36.1c	73.3b	120.1a	88.1y	178.8x	160.1x
1976–77	39.3c	67.1b	102.3a	95.9z	163.8x	136.4y
Mean	39.7c	59.7b	104.2a	96.9z	160.6x	138.9y
1978–79	54.7b		95.0a	133.4		126.7
1979–80	60.5b		121.1a	147.6		161.4
1980–81	55.5b		131.0a	135.4y		174.5x
1981–82	51.1b		106.1a	124.0		141.5
1982–83	52.1b		101.8a	127.0		135.8
1983–84	45.4b		98.3a	110.8		131.1
1984–85	40.3b		84.8a	98.4		113.0
1985–86	30.1b		77.6a	73.4		103.5
Mean	48.7b		101.9a	118.8		135.9

the last 2 periods (Table 6). There was little difference in carcase grade in these periods.

Effect of oversowing siratro into native pasture. Oversowing siratro into killed native pasture ($N_{0.41}$ *vs* $NS_{0.41}$) significantly (P<0.01) increased both carcase weight and depth of back fat in all drafts. While dressing percentage was higher in $NS_{0.41}$ in all drafts, differences were significant (P<0.01) in only 2 of the 4 drafts (Table 6). Further, <10% of $N_{0.41}$ carcases rated Grade 1 compared with >90% of carcases from $NS_{0.41}$.

Effect of replacing oversown native pasture with sown pasture. Comparing oversown native pasture and replacement pasture (NS and BS) at common stocking rates of 0.58, 0.75 and 0.93 hd/ha, generally carcase weights, dressing percentages and depths of back fat were higher from the replacement pasture (Table 6). However, in only the first draft was the difference significant (P<0.01). There was little difference between treatments in carcase grade with >90% of carcases from both treatments rating Grade 1.

Relationships between pasture and liveweight gain

There was no consistent relationship between autumn green yield of pasture and annual LWG/hd. LWG/hd increased with increasing green yield for the BS treatment, with the slope of the trend significantly different from zero. However, green yield explained only 50% of the variation (Figure 6a). For the other treatments, green yield explained <20% of the variation and the slopes of the regressions were not significantly different from zero (P>0.05). A similar result was found when LWG/hd was related to available green yield per animal. Comparisons done over shorter time periods did not improve the correlations.

When LWG/hd was compared with percent utilisation, the relationships were similar, but in reverse. LWG decreased with increasing level of utilisation for the BS treatment (P<0.01), again explaining approximately 50% of the variation (Figure 6b). Again, trends for the other treatments were not significantly different from zero. Interestingly, all lines converge at a utilisation rate around 100% with a LWG of around 120 kg/hd. Figure 6 shows utilisation rates exceeding 50% in many years for both NS and BS pastures. In Phase II, the utilisation rate in the NS treatments averaged 38% and 70% at 0.75 and 1.11 hd/ha, respectively, 55% in the BS treatment and 31% in the N treatment.

Other animal-pasture-climate relationships were examined, but no pasture or climatic predictor (or combination of predictors) of animal LWG could be found that explained more then 70% of the variation, and was reliable across years.

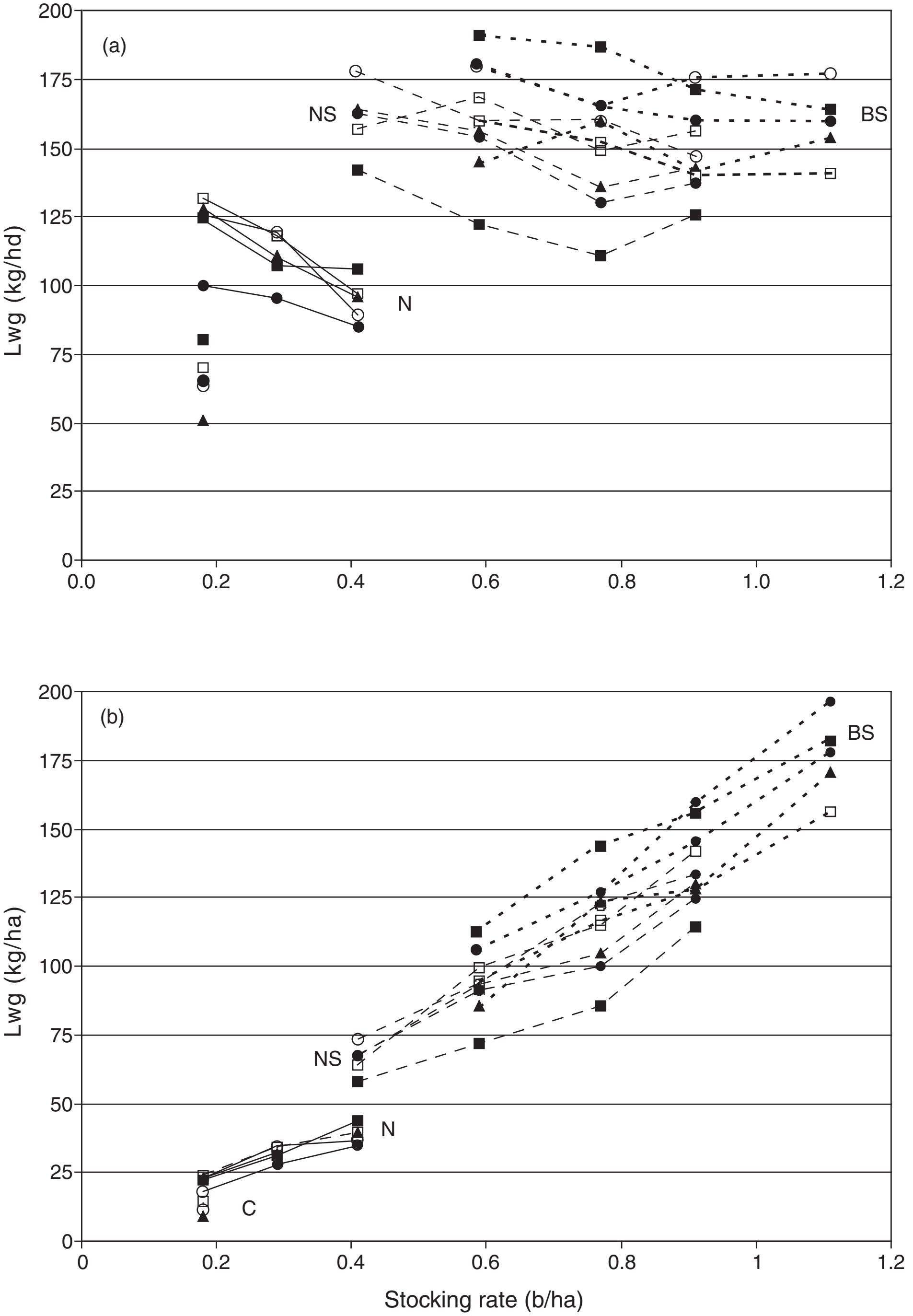


Figure 3. Stocking rate effects within the main treatments on annual liveweight gain of steers over 1972–77: (a) kg per head and (b) kg per hectare. 1972–73 (■), 1973–74 (●), 1974–75 (□), 1975–76 (○) and 1976–77 (▲).

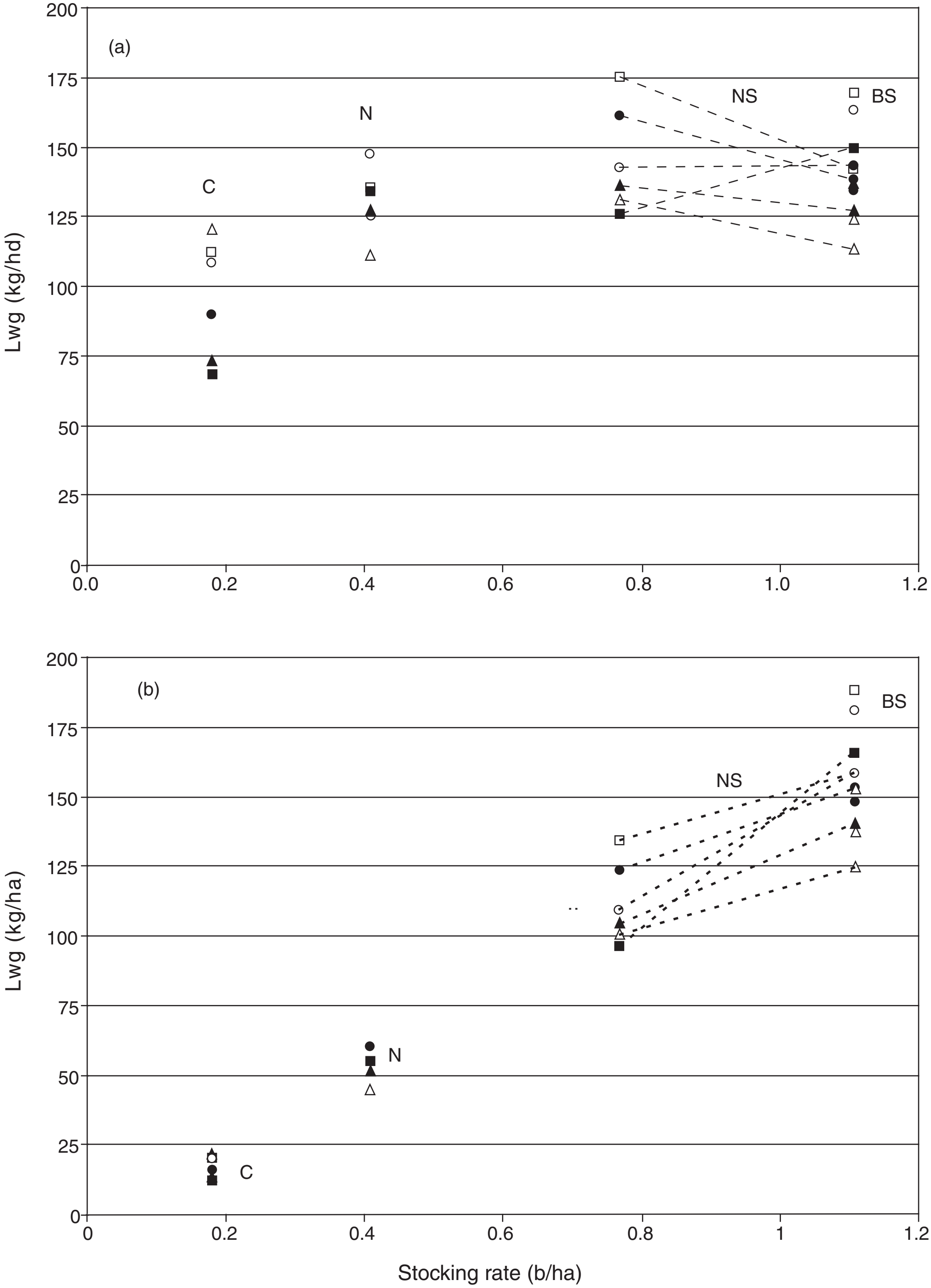


Figure 4. Stocking rate effects within the main treatments on annual liveweight gain of steers over 1979–86: (a) kg per head and (b) kg per hectare. 1978–79 (■), 1979–80 (●), 1980–81 (□), 1981–82 (○), 1982–83 (▲), 1983–84 (△).

Table 5. Annual liveweight gains of steers on black speargrass pasture improved with siratro (NS) and replacement pasture of buffel grass-siratro (BS) for 1972–86. For the period 1972–77, values for NS and BS treatments are averaged over stocking rates of 0.58, 0.75 and 0.93 hd/ha. Within years, values followed by different letters (a,b for kg/ha and x,y for kg/hd) differ (P<0.01).

Treatment	NS		BS	NS		BS
No. animals	24		24	24		24
Years	(kg/ha)			(kg/hd)		
1972–73	98.0b		134.7a	129.8y		180.4x
1973–74	104.4b		124.8a	139.7y		167.4x
1974–75	117.9		111.3	157.5		149.4
1975–76	116.4		129.9	155.5		172.6
1976–77	107.9		115.5	144.2		148.5
Mean	108.9		123.2	145.3		163.7
Treatment	NS$_{0.75}$	NS$_{1.11}$	BS$_{1.11}$	NS$_{0.75}$	NS$_{1.11}$	BS$_{1.11}$
Stocking rate (hd/ha)	0.75	1.11	1.11	0.75	1.11	1.11
No. animals	10	8	8	10	8	8
1978–79	95.0b	174.0a	164.6a	126.7	156.8	148.3
1979–80	121.1b	153.4a	149.7ab	161.4	138.2	134.5
1980–81	131.0c	157.4b	188.1a	174.5x	141.8y	169.5x
1981–82	106.1c	149.2b	180.4a	141.5	134.4	162.5
1982–83	101.8b	141.1a	151.8a	135.8	127.1	136.8
1983–84	98.3	124.5	136.7	131.1	112.2	123.1
1984–85	84.8	110.4	114.8	113.0	99.5	103.4
1985–86	77.6	95.9	85.2	103.5	86.4	76.7
Mean	101.9b	138.2a	146.3a	135.9	124.6	130.9

Discussion

Overall animal production

This study has demonstrated that animal production in terms of both LWG/hd and LWG/ha can be increased progressively with increasing level of development (C<N<NS<BS). Merely removing trees from the native pastures (Treatment N) allowed an increase in stocking rate from 0.18 hd/ha on the native woodland (C) to 0.41 hd/ha with resultant LWG/ha 3 times that from the native woodland. The 'tree removal' effect persisted for at least 11 years, up to 1983, and most likely would have continued. The lack of difference in the final years (1983–86) was probably due to the severe drought of 1982–83 followed by low rainfall and pasture production in 1984–86 (Tothill *et al*. 2008) having an overriding effect. Where a legume was included and fertiliser applied (NS and BS pastures), LWG/hd was some 30–50% higher than that from native pastures (N) allowing turn off at a younger age. As these pastures were able to support higher stocking rates, LWG/ha was approximately 3- and 4-times higher, respectively, than for native pastures. The animal productivity from BS and NS pastures is similar to those reported for southern Queensland by Mannetje and Jones (1990) and Walker (1977), respectively, and is similar to those from buffel-cassia (*Chamaecrista rotundifolia* cv. Wynn) and buffel-stylo (*Stylosanthes scabra* cv. Seca) pastures reported by Jones *et al.* (2000), and from speargrass plus mixed legume pastures (MacLeod and McIntyre 1997). Similar increases in animal production from improved pastures in southern Queensland have been reported by Shaw and Mannetje (1970, 6-fold) and Bowen and Rickert (1979, 8-fold) using *Stylosanthes* species, and by Nicol *et al.* (1982, 5-fold) using siratro, but the increases were much greater than those reported by Gardener *et al*. (1993) on a fertile soil in north Queensland. The increased production came from a combination of increased stocking rate and increased LWG/hd.

The increased LWG/hd from siratro-based pastures (BS and NS) with associated higher dressing percentage produced an added benefit as most carcases were classed as Grade 1 (which attract a premium price), whereas those from the native pasture alone (C and N) were mostly Grade 2 or 3. Mannetje and Jones (1990) reported similar benefits in carcase quality from improved pastures. This highlights the importance of not

Table 6. Carcase weights, dressing % and depth of back fat at the 12th rib for 2.5-year-old steers after 2 years on the experiment. Dressing % equals dressed weight as a percentage of final live weight. Within years, values for each paired comparison ($C_{0.18}$ *vs* $N_{0.18}$, $N_{0.41}$ *vs* $NS_{0.41}$ and NS[1] *vs* BS[1]) followed by a different letter are significantly different (P<0.01), adjusted for initial live weight.

Period	$C_{0.18}$	$N_{0.18}$	$N_{0.41}$	$NS_{0.41}$	NS[1]	BS[1]
Carcase weight (kg)						
1972–74	139.0b	195.2a	187.1f	255.5e	221.0y	272.7x
1973–75	154.3b	193.9a	192.5f	252.0e	257.7	266.1
1974–76	115.6b	191.6a	139.4f	250.7e	232.9	247.5
1975–77	129.2b	205.1a	171.3f	272.2e	242.1	258.6
Mean	136.3b	196.7a	173.8f	258.5e	238.4y	253.2x
Dressing (%)						
1972–74	45.2	47.3	47.6	50.6	48.7y	51.1x
1973–75	44.2	46.4	47.0	51.1	51.8	51.8
1974–76	40.4b	45.8a	42.6f	50.3e	50.6	50.9
1975–77	41.9b	46.2a	44.3f	50.3e	48.1	49.6
Mean	43.0b	46.6a	45.4f	50.6e	49.8	50.8
Back fat depth (mm)						
1972–74	1.8	2.9	3.3f	7.4e	5.5y	10.9x
1973–75	2.2b	5.6a	4.8f	9.0e	11.5	10.8
1974–76	1.8b	5.1a	2.0f	14.1e	8.3	9.8
1975–77	1.2b	4.0a	3.0f	11.1e	8.5	10.0
Mean	1.8b	4.4a	3.2f	10.4e	8.3	10.6

[1] Values for NS and BS are means of stocking rates 0.58, 0.73 and 0.93 hd/ha.

relying on liveweight gain alone as the criterion for comparing treatments. It should be noted that fertiliser was used on both siratro-based pastures while none was used on the native pastures; hence, the improvement in performance should not necessarily be attributed solely to the presence of legume, as minerals applied in the fertiliser might have contributed. Gillard (1979) and Shaw (1978) both reported increases in LWG with the use of fertiliser on native pastures, even without an introduced legume. McLean and Ternouth (1994) reported a similar increase on a buffel grass pasture, attributed to increased intake by the animal, of not only dry matter, but also phosphorus.

The superior performance on the siratro-based pastures in autumn and winter (Figure 5) supports the reports by Mannetje and Jones (1990) for buffel-siratro pastures and Jones and Jones (2003) for coastal setaria-siratro pastures. The contribution of nitrogen to the diet by the legume as the associated grasses matured would have allowed animals on these treatments to make better gains than those on straight grass pastures. However, in north Queensland, Gillard (1979) found most benefit from legume occurred in the wet season. The lower weight gains on native woodland in spring relative to those on the other pasture types are most likely a reflection of competition for moisture with the trees, resulting in lower spring yields (Tothill *et al*. 2008). Similarly, the higher gains in spring from the fully sown pasture than from N and NS pastures can probably be attributed to the ability of buffel grass to commence growth at lower temperatures than the native speargrass.

It is significant that LWG/hd on the native pasture control and native pastures without trees was higher in the drier Phase II than in Phase I, while gains on the siratro-based pastures declined. This highlights the complexity of the plant-animal interaction in rangelands, and the need for stock numbers to be adjusted annually, depending on pasture growth. The differences between phases also highlight the advantages of continuing grazing experiments over long time periods when working in rangelands (Jones *et al*. 1995a).

Stocking rate effect

The decrease in LWG/hd of 20–50 kg/unit increase in stocking rate on siratro pastures is consistent with the values quoted by Mannetje and Jones (1990). However, using the linear model of Jones and Sandland (1974), the calculated optimum stocking rates for maximum animal production of 0.6, 2.0 and 3.6 hd/ha for the N, NS and BS treatments, respectively, far exceed the highest stocking rates used in this study. While it is not unusual for stocking rate impacts from early years of grazing trials to be potentially misleading (Mannetje and Jones 1990; Jones *et al.* 1995b; Jones and Jones 2003), the calculated optimum for the NS treatment in the drier Phase II was even higher at 2.5 hd/ha. During Phase II, the NS pasture was mostly native grass, hence the utilisation rates of 38% ($NS_{0.75}$) and 70% ($NS_{1.11}$) were well above the generally accepted rate of 30% for native pasture (Gardener *et al*. 1993; Partridge 1993), so even the lower stocking rate was unsustainable. Similarly, the average utilisation of 31% for the native pasture was on the 30% limit, while the average of 55% for the buffel-siratro pasture was excessive, given that, in some years, the utilisation rates would be much higher. Hence, the calculated optimum stocking rates far exceed any reasonable sustainable level. Similar excessive optimums were calculated by Jones (2003) for native and sown pastures in north Queensland.

Further, in both the NS and BS treatments, the LWG/hd was actually higher at the highest stocking rate than it was at the next lower rate. Hence, if either the third or fourth stocking rate had not been included in the design, the calculated optimums rates would be completely different. These results support the findings of Ash and Stafford Smith (1996) that the linear stocking rate model is not suitable for general application in the rangelands. In rangeland conditions, to determine the so-called optimum, the regression line for LWG/hd *vs* stocking rate has to be extrapolated well beyond the data used to predict it. This is both biologically and mathematically invalid. For a particular environment of interest, it is far safer to use relevant published literature and personal experience to determine a sustainable stocking rate that maximises animal or economic return.

Based on utilisation rates and pasture yield and composition, sustainable stocking rates for these pastures are probably around 0.2, 0.33, 0.4 and 0.67 hd/ha (*i.e*., 5, 3, 2.5 and 1.5 ha/b), for the native woodland, native (trees killed), native-siratro and buffel-siratro pastures, respectively. Although the native (trees killed) pasture was stocked at 0.41 hd/ha in the second phase

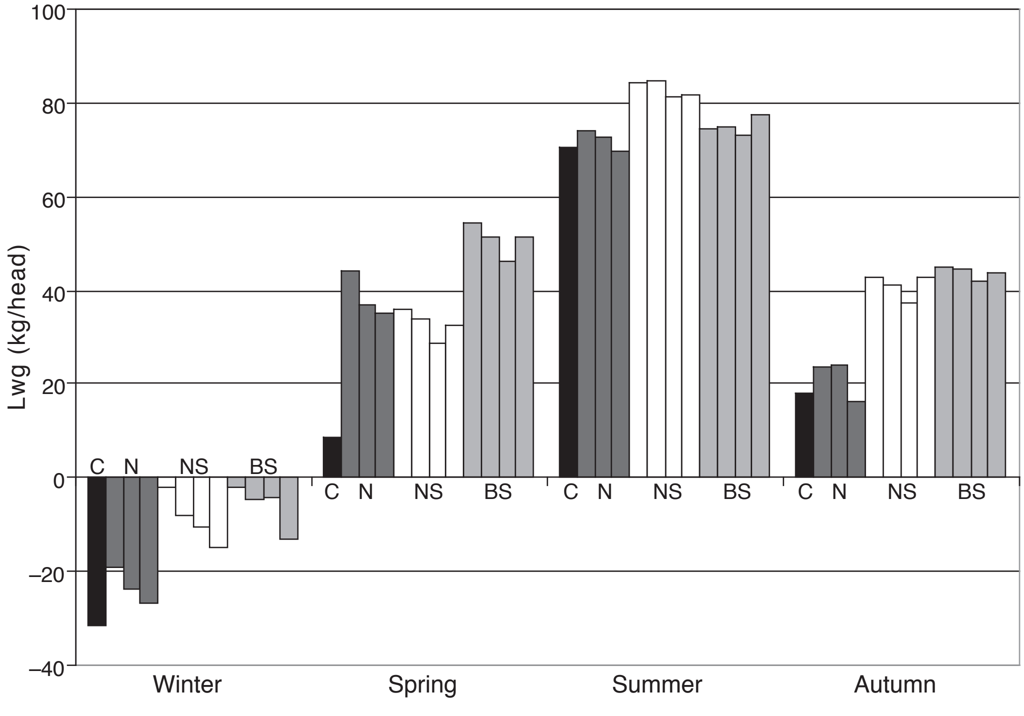
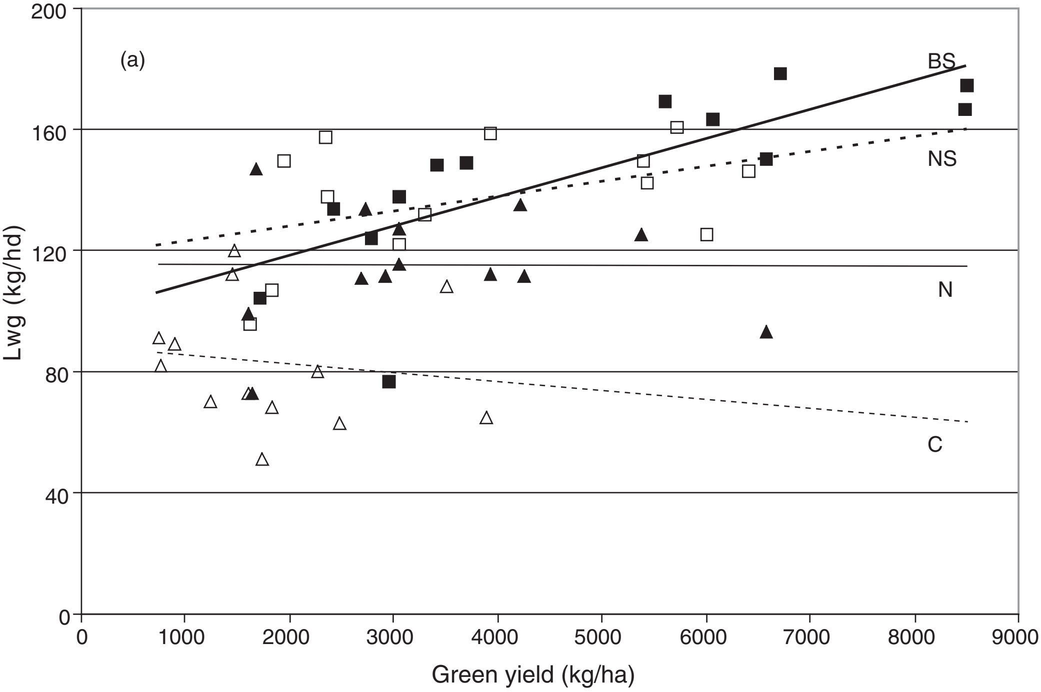


Figure 5. Seasonal stocking rate effects within main treatments on liveweight gain of steers in kg per head, averaged over 1972–77. C at 0.18 hd/ha, N at 0.18, 0.29 and 0.41 hd/ha, NS at 0.41, 0.59, 0.77 and 0.91 hd/ha, BS at 0.59, 0.77, 0.91 and 1.11 hd/ha. Stocking rates increase from left to right within each main treatment.



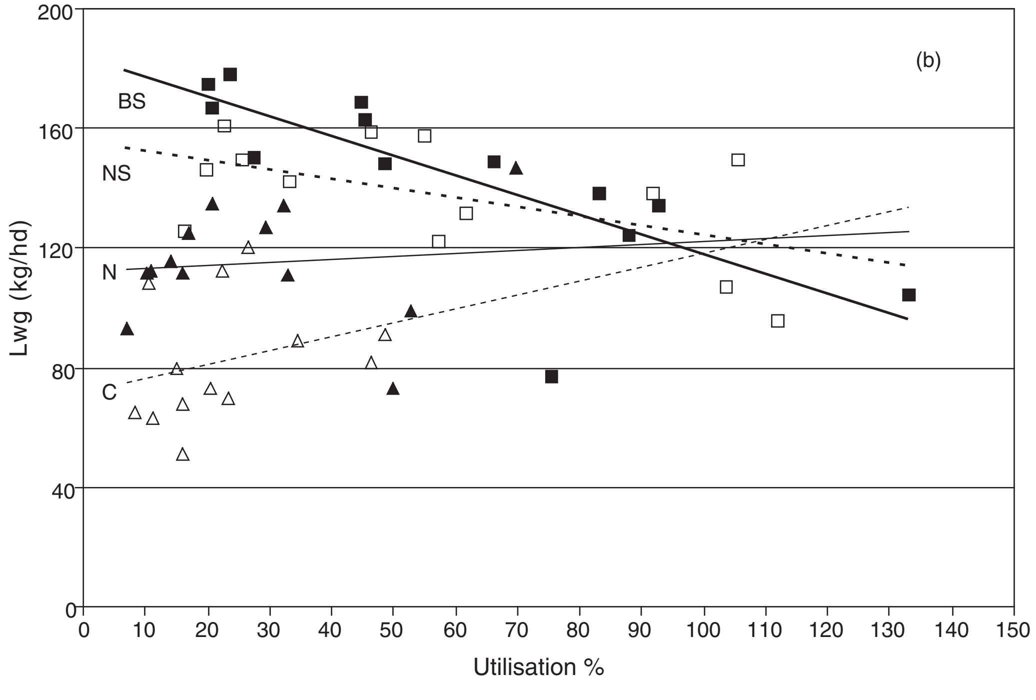


Figure 6. Relationship between liveweight gain per head and (a) autumn green yield and, (b) utilisation percent. BS (■), NS (□), N (▲), C (△).

and animal production increased, there were increasing amounts of undesirable species in the pasture (Tothill *et al*. 2008) and it was clear that this stocking rate was not sustainable in the long term. MacLeod and McIntyre (1997) found a rate of 0.6 hd/ha led to a decline in speargrass dominance in a speargrass plus mixed legume pasture. The decline in siratro and increase in undesirable species in the NS pastures in this trial (Tothill *et al*. 2008) suggest a stocking rate closer to the N pasture would be a more appropriate level. However, siratro has been found to decline over time even at low stocking rates in this region (Mannetje and Jones 1990). While other legumes such as stylo and cassia have been found to be more persistent than siratro in this environment (Partridge and Wright 1992; Jones *et al.* 2000; Orr *et al*. 2001), when oversown into native pastures, these legumes can become dominant at higher stocking rates. A good grass-legume balance is desirable for stability. While the BS pasture continued to provide reasonable LWG/hd at the end of the study, again siratro had almost disappeared and the growth of buffel grass had declined to very low levels. A stocking rate of 0.75 hd/ha or lower would be beneficial for buffel grass recovery and would enhance siratro survival.

Animal-pasture relationships

Despite extensive investigation, no relationship between the measured pasture and climatic attributes was reliable across years (McDonald and Ash 2005). Relationships need to explain at least 70% of the variation in a particular parameter as this amount of variation can often be explained with trivial predictors such as daily maximum temperature (Evans and Wilson 1984), or in some areas, daily radiation. This highlights the complexity of the animal-pasture relationship in this environment. Jones and Jones (2003) reported a reliable relationship for areas of higher rainfall and less complex coastal pastures. McCaskill and McIvor (1993) reported similar poor relationships in north Queensland to those reported here. This suggests more detailed study is required to understand animal diet selection in this environment, particularly in native pastures. The good relationships with green days, as reported by McCown (1980–81) and Jones (2003) in north Queensland, are probably due to the distinct wet and dry seasons experienced in that region and do not apply in southern Queensland where winter rainfall promotes growth of cool season forbs. It is known that animals can consume large quantities of these forbs (Jones and Bunch 1999). As shown by Mannetje (1974), reasonable relationships could be found with green yield in BS pastures for individual years. However, there was large year-to-year variation in the relationship. This is a widespread problem as others have reported better relationships with dry material than green (Ebersohn *et al*. 1985; Piaggio and Prates 1997).

The problem relates to predicting diet quality. This is indicated by the better production from native pastures in the second phase. When plants are under stress, the ageing of leaves is delayed and leaves have increased digestibility (Wilson 1983) and nutrient levels (Wilson 1982). Consequently, in drier years, although there is less growth, there is also less dilution of available nutrients, particularly nitrogen, leading to higher quality feed (Wilson and Minson 1980; Ash and Stafford Smith 1996). Similar increases in pasture quality with declining grazing conditions have been reported by Ash and McIvor (1995) at low stocking rates in north Queensland, with a subsequent increase in LWG/hd (Ash *et al*. 1995). Further, green leaf produced by a grass plant early in the season is of much higher quality than leaf produced later in the season (Wilson and Minson 1980). Legumes can increase the quality of companion grass (Osman and Abu Diek 1982) and increase diet quality and feed intake (Ash and McIvor 1998). Conversely, the removal of trees can decrease these parameters (Ash and McIvor 1998).

Economic benefits

The potential benefits from improved pastures are not limited to the increased LWG/ha and the better quality carcases produced, but include reduced time to turnoff. Assuming animals were weaned at approximately 6–8 months of age at a weight of around 180 kg (Bortolussi *et al*. 2005a), and gained weight at annual rates as given in Table 7, they could reach a marketable weight for the Japanese Ox trade (≈600 kg liveweight) in 2.5, 3, 4 and 5 years, respectively, for the BS, NS, N and C pastures, at the stocking rates used here. However, in this region, animals would probably be sold for fattening prior to reaching 5 years of age.

Oversowing siratro into cleared native pasture more than doubled gross income after 3.5 years, and a fully sown pasture increased gross income 4-fold. Further, for an enterprise with breeding animals, these pastures have been shown to improve calving rates and weaning weights compared with native pastures (Mannetje and Coates 1976). However, the economic benefits of oversown and fully sown pastures need to be reconciled against the capital outlay required to establish these pastures, the longevity of the introduced pastures, and other running costs, to determine a gross margin. It should be noted that the values shown in Table 7 are generalised estimates and should be taken as a guide to the relative differences only. The actual pasture and animal production and revenue from sales will vary between properties, between managers, breed types, run of seasons, political decisions in Australia and abroad, and so on.

While the high stocking rates used in this trial resulted in high LWG/ha, there was a penalty in lower LWG/hd, dressing percentage and carcase quality, compared with those expected at the more sustainable stocking rates suggested. However, at the present time (2007), there is no penalty in price/kg at slaughter from the same pasture type, but there are penalties between pasture types (Table 7), *i.e.,* there was more difference in price/kg between pasture types than between stocking rates. Reducing the stocking rates to more sustainable levels would decrease gross income considerably for the native pasture, and would reduce income from the siratro-based pastures by over 30% (Table 7), highlighting the trade-off that exists between economic and ecological optimums (MacLeod and McIntyre 1997).

Conclusions

Progressively developing the native woodland by killing trees, oversowing siratro plus P fertiliser, or sowing a replacement pasture of buffel and siratro plus P fertiliser, progressively increased both pasture and animal production, as well as gross income/ha (Table 7) by as much as 3- to 4-fold. While the stocking rates are suggested as being sustainable in the long term, and are similar to those advocated for the broader southern speargrass region (Partridge 1993), the variability in pasture growth between years means it is essential that stocking rate be adjusted on an annual basis.

Table 7. Development options and levels of sustainable use for the southern speargrass region. Ha/AE is based on an Animal Equivalent equal to a 500 kg non-lactating animal. Final liveweight assumes the animals are turned off 3 years after weaning (*i.e.*, at 3.5 years, 6-tooth) aimed at the Japanese Ox market, and start with a weaning weight of 180 kg. The gross income is the return/ha at the end of 3.5 years.

Grass Trees Legume	Native + trees Nil	Native – trees Nil	Native – trees + siratro + P	Sown grass – trees + siratro + P
Development cost	NIL	LOW	MODERATE	HIGH
Production at trial stocking rates				
Hd/ha	0.18	0.41	0.75	1.11
LWG/hd/yr (kg)	65–95	95–130	130–150	140–160
LWG/ha/yr (kg)	12–18	35–55	95–115	155–180
Final Lwt (kg)	420	510	600	630
Dressing %	43	46	51	53
Carcase weight (kg)	181	235	306	334
Price (c/kg dressed wt)	160[1]	263	291	291
Gross income ($/ha)	121[2]	253	668	1079
Estimated production at suggested sustainable rates				
Hd/ha	0.2	0.33	0.4	0.67
Ha/hd	5.0–6.0	2.5–3.5	2.0–3.0	1.0–2.0
Ha/AE	8.0–9.0	3.5–5.0	2.5–4.0	1.5–2.5
LWG/hd/yr (kg)	80	115	160	170
LWG/ha/yr (kg)	16	38	64	113
Final Lwt (kg)	420	525	660	690
Dressing %	—	47	53	55
Carcase weight (kg)	—	247	350	380
Price (c/kg dressed wt)	160[1]	263	291	291
Gross income ($/ha)	134[2]	214	407	741

[1] Price/kg liveweight as animal would not be sent to slaughter; [2] Based on sale of live animal.

Most woodland in south-east Queensland has been cleared or is protected under tree clearing guidelines, so the realistic comparison for the present is between oversown or fully sown pastures and native killed/cleared pasture. There are risks associated with such capital development but, if done properly in selected areas and managed appropriately, there is no reason why these development strategies could not be economically viable, ecologically sustainable and environmentally responsible.

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