curfews prior to slaughter (Wythes et al. 1982), and the benefit of altering the proportion of grain in the feedlot ration to satisfy market premiums.

The physical model showed that 60 head of cattle could be reliably turned off every year from 110 ha of land. Overall average production was 134 kg LWG/ha/year which was approximately a three fold increase on the 30-50 kg LWG/ha/year that could be expected from native pasture. Furthermore the ley farming system in operation on the arable soil in this system is likely to be stable in the long term and could be particularly suited for marginal cropping land.

A COMPUTER MODEL OF THE INTEGRATION OF FORAGE OPTIONS FOR BEEF PRODUCTION

G.M. McKEON# and K.G. RICKERT*

Computer models of integrated forage systems have the potential to avoid the outlay of time, space and resources required in physical models. They can consider a much greater range of management options (e.g. stocking rate, season of use, fertilizer, burning, conservation) and evaluate these alternatives against the variability of weather and prices.

The model presented here examines the integration of native and sown pastures as tested in the physical models of Robbins and Bushell (above), Scattini (1983) and Addison (1970). The management options considered are stocking rate, season of use, proportion of sown pasture in the property and direct supplementation of animals grazing native pasture in winter and spring. Future model development will include economic evaluation and analysis of year-to-year variation in pasture and animal production.

MODEL DESCRIPTION

Our aim is to develop a model of a beef enterprise with the following specifications:
1. capable of considering many combinations of management alternatives;
2. robust enough to extrapolate outside the bounds of experimental data;
3. capable of considering year-to-year variation in plant production; and
4. suitable for use in micro-computers.

In this paper, we present the basis of the biological model by considering a simple example involving the integration of only two options. The aim of the model is to predict annual liveweight gain of a weaner steer for a given grazing system. Seasonal (91 days) liveweight gain (LWG) was assumed to be related to dry matter intake (DMI). The equations of Siebert and Hunter (1977) relating intake and LWG to diet nitrogen for tropical pastures were reworked to give:

$$\underset{(kg/hd/d)}{LWG} = 0.304 \underset{(kg/hd/d)}{DMI} - 1.058; \qquad \text{(equation 1, Fig. 1a)}$$

Different management options (stocking rate, season of use) were modelled by describing their effects on dry matter intake. However, we have found (for these pastures) little relation between pasture on offer and LWG except at low pasture yields (500 kg/ha, Hendricksen et al. 1982). Hence, the usual pathway of modelling animal production by relating intake to pasture yield has not been followed. Instead we set a potential intake for each season, from equation 1 using observed LWG at low stocking rates. This potential reflects the overriding seasonal effect on diet quality. Potential intake was then reduced by

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an "intake modifier" which was calculated from the proportion of accumulated growth which had been eaten (Fig. 1b) i.e. proportion eaten since start of summer:

$$\text{proportion eaten} = \frac{\text{amount eaten since December 1}}{\text{accumulated growth since December 1}} \quad \text{(equation 2)}$$

$$\text{intake modifier} = a - b \times \text{proportion eaten} \quad \text{(equation 3)}$$

The intake modifier is constrained between 0 and 1.

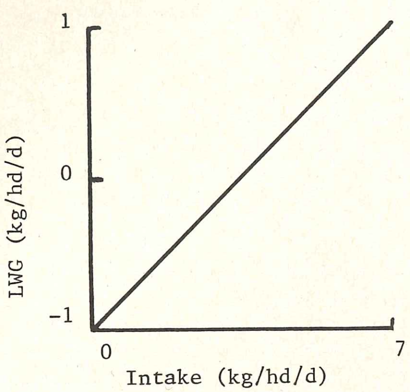

Fig. 1a Relationship between intake and liveweight gain (LWG)

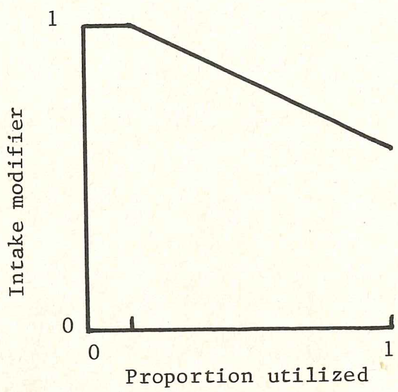

Fig. 1b Relationship between intake modifier and proportion of pasture eaten

Because of the variation in seasonal production in tropical pastures in southern Queensland, pasture yields generally exceed feed requirements. This allows increased opportunity for diet selection between pasture components (e.g. leaf and stem) at low stocking rates. The "intake modifier" attempts to describe the reduction in intake that is likely to occur due to reduced opportunity for selection with increased stocking rates or long durations of grazing e.g. year round. An analytical solution of equations (2) and (3) was used to calculate the average intake restriction for a season.

Sequence of calculations in the model:

1. Calculate accumulated pasture growth and amount eaten since 1 December.
2. Calculate potential seasonal intake (Table 3 and equation 1).
3. Calculate intake modifier as a function of previous growth and grazing, and current season's growth, potential intake and stocking rate (equation 2 and 3).
4. Calculate actual intake = intake modifier x potential intake.
5. Calculate LWG from equation 1 and update animal live weight.
6. Start again for next season.

Required inputs to formulate the model are given in Table 3: (1) seasonal pasture growth which is calculated by a pasture growth model (McKeon et al. 1982); (2) field measurements of seasonal liveweight gain at low stocking rates; and (3) effect of stocking rate on annual liveweight gain. Potential intake for each season was calculated through equation 1 using seasonal liveweight gain from Table

3. With these average inputs, equation 3 in the model was solved by fitting the model to the observed stocking rate response data for native pastures (from Brian Pastures Research Station) and for sown pastures (from Brigalow Research Station 200 km NW of Gayndah, Walker pers. comm). Solutions were: native pasture a=1.074 and b=0.486; sown pasture a=1.039 and b=0.437.

TABLE 3 Input data for model development

a: seasonal growth

Season	Native Pasture		Green Panic	
	growth (kg/ha)	LWG (kg/hd)	growth (kg/ha)	LWG (kg/hd)
Summer (Su)	1926	60	3930	75
Autumn (Au)	920	25	1349	44
Winter (Wi)	50	-4	121	26
Spring (Sp)	639	32	1616	48
Total	3535	113	7016	193

b: responses to stocking rates

SR	LWG (kg/hd/yr)	
(beasts/ha)	N.P.	G.P.
0.35	115	194
1.0	75	168
1.5	44	148
2.0	13	127
2.5	-18	107

VALIDATION

The model was tested against sixteen independent data sets from Brian Pastures where grazing was restricted to 6 month periods (Table 4). The model agreed well (residual standard deviation: 8 kg/hd) with observed data suggesting information gained from year round stocking rate relationships can be used to extrapolate to shorter grazing periods. The model correctly predicted the results of two other trials which have examined the effect of light grazing in summer/autumn on subsequent winter/spring performance. On native pasture, Addison (1970) measured a 5 kg/hd reduction in winter/spring due to summer grazing. For green panic, Scattini (pers. comm.) found a 9 kg/hd reduction in winter/spring LWG due to autumn grazing. In these two cases the model predicted a reduction of 6 and 8 kg/hd, respectively.

SIMULATIONS

A hypothetical property was considered with varying proportions of sown and native pasture. A maximum "drought-safe" stocking rate was calculated assuming that native pasture area would carry 0.5 b/ha year round and sown pasture 1.0 b/ha. Cotton seed supplementation (0.7 kg/d) on native pasture in winter and spring was simulated by increasing LWG by 9 kg/hd and 30 kg/hd respectively (Addison 1970). No effect on intake (substitution or intake increase) was considered. The various options were compared on a LWG per ha basis.

Two techniques were used to conduct simulation experiments: (1) a factorial design with 4 seasons of use and 4 possible stocking rates on one option each season (0, 0.5, 1.0, 1.5 b/ha) giving 256 combinations; and (2) the model was linked to a "hill climbing" optimization package to maximise LWG/ha. The former approach allows a better description of the overall response surface while the latter approach allows the continuum of stocking rate to be considered. However, in some cases the optimization approach gave slightly different solutions with different starting conditions. The factorial analysis indicated that a variety of combinations gave similar results although the general principle of integration was common to all optimal solutions.

TABLE 4 Comparison of observed and predicted liveweight gain for periods of seasonal grazing

Source and pasture	Seasons grazed	Years Observed	SR (beasts/ha)	Average LWG (kg/hd) Obs.+	Pred.
Addison 1970:					
native pasture	Wi & SP	1966-69	1.24	32	25
green panic	Su & Au	1966-68	1.85	92	95
native pasture	Su & Au	1966-68	0.62	80	81
Addison et al. 1984b:					
native pasture	Au & Wi	1971-73	1.24	6	17
Addison et al. 1984c:					
green panic	Sp & Su	1970-74	2.47	116	103
Scattini 1983:					
green panic	Wi & Sp	1963-69	1.49	80	72
			2.47	65	65
Robbins and Bushell (above):					
green panic	Wi & Sp	1976-81	2.40	50	65
native pasture	Su	1977-82	1.00	52	52
Scattini and Cooksley (pers. comm.);					
native pasture	Su & Au	1961-82	0.74	73	77
			1.24	69	62
			2.47	41	30
	Wi & Sp	1971-82	0.74	39*	28
			1.24	31*	25
			2.47	19*	14
Cooksley (above);					
native pasture with leucaena in Wi & Sp	Su & Au	1978-83	0.50	86	85
			1.00	81	70

\+ Where required LWG for hereford or G1 crossbred cattle was converted to a G2 crossbred equivalent: ADG(G2) = 0.804 ADG(H) + .135; ADG(G2) = 0.9 ADG(G1) kg/d

* Fed a molasses urea supplement
LWG (Pred) = 0.954 LWG (Obs) +0.772, r = 0.96, n = 17, s = 7.9

Advantages from integration reflect the degree in which the two forage options differed in seasonal production. The maximum advantage of sown pasture occurred in winter (30 kg) compared with 18 kg in autumn and spring and 15 kg in summer. As expected, the optimal solutions (Table 5) involved the use of sown pasture mainly in winter with variable use in autumn and spring. However, production from an 'optimal' integrated property did not greatly exceed (<10kg/ha) the combined production from each pasture independently grazed year round at the safe stocking rates, i.e. non-integrated use (Fig. 2a). The impact of optimal-integrated systems compared to the non-integrated use was greatest on average LWG per head for properties where sown pasture makes up a small proportion of the property (Fig. 2b). Supplementation increased LWG on native pasture in spring above sown pasture LWG and hence the optimal production was achieved by grazing sown pastures in autumn and winter.

The model showed that limited input data of pasture growth, animal production and stocking rate response can be used to simulate a wide range of combinations of stocking rate, and season of use, and hence provides a powerful tool for suggesting more refined physical models for testing.

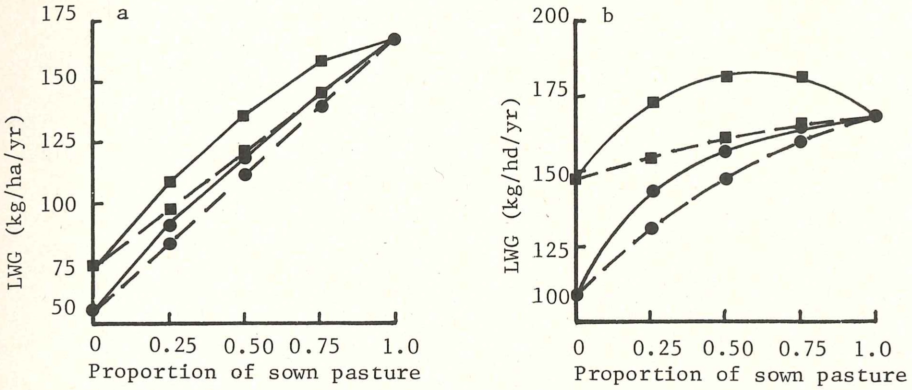

Fig 2 Liveweight gain for non-integrated pasture systems (— — —) and optimized integrated systems (———) with supplementation (■ ■) and without supplementation (● ●): (a) LWG per ha; (b) LWG per head

TABLE 5 Seasonal stocking rates (beasts/ha) that give optimum integration for different proportions of native and sown pasture with overall animal numbers determined by the safe annual stocking rates (0.5 and 1.0 beasts/ha) for each pasture

Proportion of sown pasture	Native pasture				Sown pasture			
	Su	Au	Wi	Sp	Su	Au	Wi	Sp
no direct supplementation to animals on native pasture								
0.25	.6	.3	0	.4	.6	1.5	2.5	1.4
0.5	.8	0	0	0	.7	1.5	1.5	1.5
0.75	.7	0	0	0	.9	1.2	1.2	1.2
direct supplementation in Wi and Sp to native pasture animals (+ 38 kg/head)								
0.25	.6	0	0	.8	.6	2.5	2.5	0
0.5	.6	0	0	1.5	.9	1.5	1.5	0
0.75	0	0	0	3.5	1.2	1.2	1.2	0

ENHANCING THE CREDIBILITY OF RESEARCH RESULTS

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Concern often is expressed that farmers are not responding readily to opportunities offered by integrating research results with their production systems. In this paper we assess two methods, namely physical and computer models of production systems, of enhancing the credibility of research results. We refer to preceeding papers in this contract as examples that demonstrate how important it is for innovations to be put into production systems so that implications can be observed. However, in exploring these issues it is also useful to consider the reluctance to adopt technology and what can be done to gain more rapid adoption.

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