TROPICAL PASTURES IN THE FARMING SYSTEM :

CASE STUDIES OF MODELLING INTEGRATION THROUGH SIMULATION

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ABSTRACT

A computer model of forage systems (PROBE) for growing beef cattle is described. The objective of the model is to evaluate enterprises in terms of biological and economic production considering year-to-year variation in climatic conditions and prices. Two simple case studies indicate the magnitude and relative importance of variation in weather and prices in respect to managerial decisions such as stocking rate. The model is used to examine the 'preferred' combination of oats and native pasture for producing an animal for the Japanese market.

INTRODUCTION

South-east Queensland receives sufficient rainfall to allow a wide range of farming and grazing enterprises. Forage options include native pasture, sown tropical grass pastures, grass/legume pastures (siratro, fine stem stylo, annual medics), and forage crops such as sorghum, lablab and oats (Milles 1984). Enterprises for growing and fattening cattle must not only consider how these forage options are best integrated into systems of cattle production (Addison and Rickert 1984), but also how variation in climatic conditions and prices affects the operation of such systems. Wide fluctuations in rainfall and prices have been a feature of beef production in the last 25 years (Fig. 1). Faced with this variability and a lack of data on forage integration, previous reviewers (Winks 1975; Rickert and Winter 1980; Murtagh 1980) recommended the use of mathematical models to evaluate different production systems. We describe here a computer model called PROBE (Primary Resource Options for Beef Enterprises) which evaluates the integration of forages considering <u>climatic</u> and <u>price</u> variability.

MODEL DESCRIPTION

The derivation of the equations in PROBE and the computer program are described elsewhere (McKeon *et al*. 1986). A description of the biological and economic processes in PROBE is given here.

Forage production

PROBE follows several other studies that relate temporal variation in forage production to rainfall and temperature (White 1978; Peake *et al*. 1979; McCown 1980-1; McKeon *et al*. 1982). A soil water balance model WATSUP (Rickert and McKeon 1982) is combined with temperature and solar radiation relationships (Fitzpatrick and Nix 1970) to produce a daily plant growth model (McKeon et al. 1982). Pasture or forage production is determined by (a) temperature response; (b) transpiration efficiency (kg/ha/mm); (c) potential regrowth (McKeon et al. 1980) when there is no green cover; (d) decision rules for seedling emergence of forage crops, and (e) rates of herbage detachment and disappearance. Data from previous agronomic experiments were used to determine these parameters: Scattini (1981) for native pastures, Robbins (1984) for green panic; and Hendricksen (1970, 1981) for oats and lablab.

Forage quality

PROBE uses seasonal potential liveweight gain for weaner steers (6 to 18 months old) to reflect seasonal variation in forage quality. Here "potential" refers to maximum expected liveweight gain if there is sufficient forage. Year to year variation in seasonal potential liveweight gains was simulated by empirical equations which consider variation in:

1. forage quality due to frost, moisture stress and nutrient dilution (Wilson and Mannetje 1978; Wilson 1982);
2. diet preference for new growth as represented by length of growing season (McCown 1980-1) or presence of herbs and forbs (McLennan et al. 1985); and
3. rainfall effects on forage quality or animal behaviour (Evans and Wilson 1984).

Liveweight gain

McKeon and Rickert (1984) showed that the observed reduction in liveweight gain (kg/head) with increasing stocking rate (head/ha) could be modelled by relating intake (kg/head) to the proportion of accumulated growth that had been eaten, i.e. % utilization. Since disappearance rates are slow in tropical forages in sub-humid conditions (Robbins 1984), % utilization can be expressed simply as the ratio of total intake to accumulated growth from the start of the growing season (1 December). Validation against independent data showed that stocking rate effects and different forage sequences could be modelled using the same framework (McKeon and Rickert 1984).

Production systems

Liveweight data were from young (6-18 months old) animals. Extrapolation to other ages and classes to simulate final liveweight of market animals was made using relationships derived from experimental data where animals of different ages grazed the same pasture. However, evaluation of production systems cannot be in terms of liveweight gain only. Carcass quality (fat score) and relative premium also influence income from sales. These were estimated by equations developed from data collected at Cannon Hill Saleyards (Williams and Moorhouse 1976). The price relationships established by Wicksteed (1980) for different ages and sexes can also be used in the model. A simple gross margin was calculated by subtracting from sales income, the costs of buying weaners, animal health, forage production (e.g. costs of planting, fencing) and drought feeding. Costs of transport and interest on livestock capital can be included if desired.

While exact representation of a growing-cattle property is not possible with the limitations of computer time and money, it is still necessary to include biological and managerial feedbacks in the evaluation of designs. One important feedback included in PROBE is the effect of overgrazing on subsequent forage production (Scattini 1973).

<u>Management variables in PROBE</u>

1. Forage sequence: For each season in the animal's life (12 from weaning to turnoff at 42 months) a paddock (1 to 13) is defined. The type of forage and area of paddocks are also defined and any sequence of paddocks can be used. The overall property size remains constant for a given forage sequence. The forages for which data have been analysed are:
(a) cleared native pasture, (b) low N green panic, (c) high N green panic, (d) fine stem stylo/grass pastures, (e) lablab, (f) oats)

2. Age and season of turn-off.

3. Number and weight of weaner steers bought each year.

4. Drought management strategies:
   (a) letting animals die at a critical weight (75% of previous maximum weight);
   (b) feeding to maintain weight above critical weight; or
   (c) forced selling at critical weight.

5. Flexible grazing management for forage crops:
   (a) if forage production is surplus to requirements either, graze additional stock at same time or graze surplus feed next season; or
   (b) if forage production is less than requirements either, sell stock when critical liveweight reached, destock to specified paddock or split the herd to fatten some and graze others on separate paddock.

Thus different forage sequences can be designed for growing and fattening steers. The operation and production of different enterprises were simulated using 30 years (1955-1984) of data on prices and climatic conditions at 'Brian Pastures', Gayndah, Queensland (Fig. 1).

SIMULATION STUDIES

To demonstrate the importance of variability in climatic and economic conditions in evaluating beef cattle enterprises we chose case studies based on a simple native pasture enterprise which has been measured at 'Brian Pastures' Research Station since 1979. Each year Saiwal-Hereford cross steers commenced grazing at the start of winter at 6 month old and were sold 3 years later at the end of autumn. All ages grazed in the same native pasture paddock at an overall stocking rate of 0.6 weaner equivalents/ha (3 ha/adult equivalent). The paddock was cleared and half was burnt each year in spring.

The results have been used with data from other experiments to develop equations of (a) potential seasonal liveweight gain and (b) the effect of animal age on liveweight gain. From 1979-1984 average liveweight gain of weaner steers was high for native pasture (136 kg/head/year) and average final liveweight at 42 months of age was 556 kg/head. The model accurately simulated year-to-year variation in seasonal liveweight gain (Fig. 2). However, validation of the liveweight gain model against independent data is not possible because of breed changes and site effects e.g., exposure to frosts, presence of winter weeds.

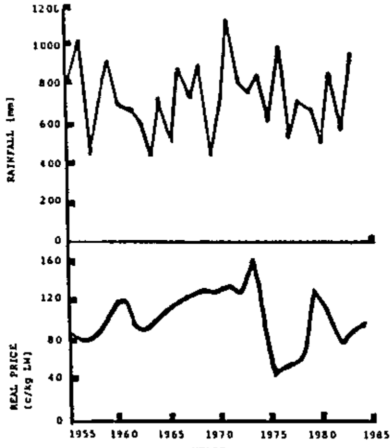

Fig. 1. Annual variation in rainfall at 'Brian Pastures' near Gayndah, Queensland and prices at Cannon Hill, Brisbane (Daly 1983) adjusted to 1984 real price.

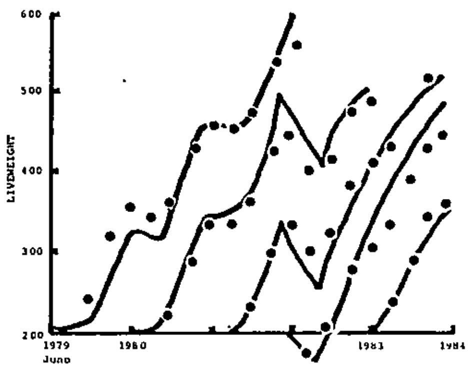

Fig. 2. Observed (——) and predicted (●) liveweight for steers grazing cleared native pasture at 'Brian Pastures'. Cattle were weighed monthly, whilst predictions are made on a seasonal (91 day) time step.

<u>Source of variability</u>

The three sources of variability, which were evaluated by simulating income from the simple native pasture enterprise, were:

1. <u>plant production</u> which determined the level of forage utilization at fixed stocking rates;
2. <u>potential liveweight gain</u> (PLWG) which indicated forage quality; and
3. <u>prices</u> which determined costs and returns.

Plant production is mainly dependent on growing-season rainfall, while potential liveweight gain is dependent on the length of the growing season and frost occurrence.

The impact of different sources of variability on income from the above native pasture enterprise was evaluated using daily climate records from Brian Pastures Research Station (1955 to 1984) and prices adjusted to 1984 dollars (after Daly 1983). Both prices

($/kg liveweight) and annual rainfall had the same co-efficient of variation (26% of mean, Table 1) but were not significantly correlated (r = .10). Temporal variation in climate e.g. droughts affect plant production and potential liveweight gain (i.e. forage quality) in different ways and the sub-models described above were used to generate historical time trends of these biological variables. The coefficient of variation on plant production was greater (30%) but variability in potential liveweight gain was lower (22%). Annual plant production and annual potential liveweight gain were not significantly correlated (r = -.33).

TABLE 1

Components of annual variability for period (1955-1984) on cleared native pasture at 'Brian Pastures'.

Components of variability	Mean	% cv*
Rainfall (mm)	730	26
Plant growth (t/ha)	3.5	30
Potential liveweight gain (kg/weaner)	173	22
Price ($/kg LW)	1.03	27

* co-efficient of variation

Comparison of the effect of the three sources operating alone showed that price fluctuations caused most variability in gross margin (Table 2). The variability from plant growth and potential liveweight gain was not additive. Variability in gross margin with all sources varying was similar to that of price varying alone (plant growth and potential liveweight gain held constant). However, in the latter case there was a 20% overestimate of gross margin.

TABLE 2

Impact of year-to-year variability on gross margin from cleared native pasture grazed at 0.6 weaner equiv/ha (3 ha/AE with turn-off at 42 months.

Source of Variation	Gross Margin $/ha		
	Mean	%cv*	Range
Plant growth alone	47	17	31-58
PLWG**	50	17	37-69
Plant growth and PLWG together	45	20	30-63
Price alone	52	35	13-91
(Plant growth, PLWG and price in combination	43	36	15-92

*co-efficient of variation
**PLWG = potential liveweight gain

The importance of simulating biological variability in evaluating management options was examined for the above enterprise, considering stocking rate as the simplest management decision. Liveweight production and gross margin for one "average year" was compared with the average of 30 years using the input of the historical time course of plant growth, potential liveweight gain and prices. The results (Fig. 3) show that, at high stocking rates, large differences occur between an "average year" and average of 30 years. The optimum stocking rate based on LWG/ha was reduced by 30% in the latter case. Analyses of the probability distributions from the 30 years simulation showed that the variability of production and gross margin increased with increasing stocking rate and difference in optima resulted from the large effect of 'bad' years. This case study shows that, in evaluating management decisions, it was necessary to consider climate-derived biological variability because, an evaluation for one "average year" would have led to a different (probably wrong) conclusion. Gross margin response to stocking rate depended on interest rate and relative price of weaners to fat bullock prices (Wicksteed 1986). However, calculation for an'average' year overestimated gross margin by 20-50% compared to the average of 30 years simulation.

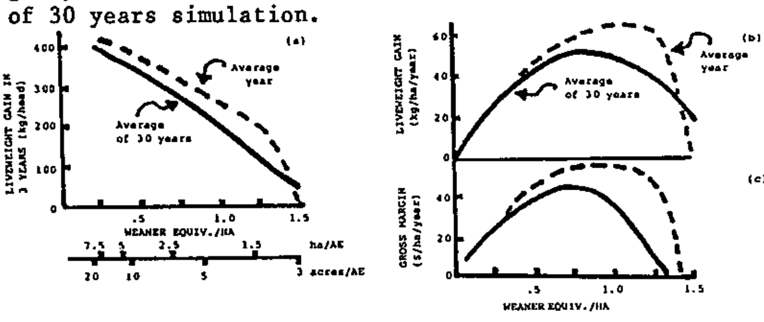

Fig. 3. The effect of stocking rate on (a) liveweight gain per head, (b) liveweight gain per ha, and (c) gross margin per ha, for an average year (---) and the average of 30 years (—).

Other environmental factors such as the presence of trees, soil type, micro-relief and aspect, result in different plant growth and forage quality (expressed as potential liveweight gain). Simulations with the model showed that there were different optimal stocking rates for different combinations of plant growth and forage quality. This highlights the difficulty of managing different resources without knowledge of production characteristics. However, once these have been determined, the PROBE model provides a framework for determining through simulation, the 'best' integration of resources.

<u>Use of PROBE in the integration of forage options</u>

Rickert <u>et al</u>. (1985) suggested that the greatest increase in production from integration was likely to occur where feed sources have markedly different growth patterns e.g., tropical grasses compared with oats. Clewett <u>et al</u>. (1986) have suggested that in central Queensland more use of oats could be made in beef production systems. In the following case study, we have used PROBE to examine, for the above native pasture enterprise, what combination of stocking rate and proportion of property sown to oats would 'best' meet the needs of the Japanese Ox market (> 580 kg/LW/head at 42 months of age).

The following management rules were made in the simulation experiment.

1. The enterprise consisted of a property (constant area) with two paddocks of varying size containing oats and native pasture. Steers were bought at 6 months and sold at 42 months as above.
2. Oats were available for grazing only in winter (1 June to 31 August). Oats were grazed with oldest animals and if there was surplus feed, other ages grazed for a proportion of the season.
3. In years where no oats crop was grown or feed was insufficient for the whole season's grazing by the older animals, all animals were grazed on the native pasture paddock.
4. Animals were fed in years with feed shortage on native pasture to prevent liveweight loss below a critical weight.

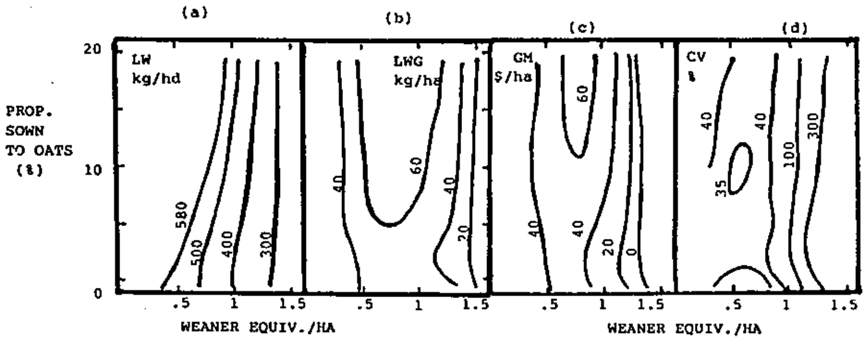

Fig. 4. Simulation of production from combination of oats and native pasture for different stocking rates (a) final liveweight, (b) liveweight gain per ha, (c) gross margin per ha and (d) coefficient of variation.

The enterprise was simulated using 30 years of native pasture and oats growth, PLWG for native pasture as before and prices. Simulation results (Fig. 4) showed that as property stocking rate increased, an increasing proportion of oats was required to achieve 580 kg final liveweight. Further simulations were carried out using combinations which gave average final liveweight of 580 kg (Fig. 4) and these combinations were compared for gross margin variability and for stocking pressure on the native pasture paddock (Table 3, Fig. 4b). In this example, combinations 10-15% oats with overall property stocking rate of 0.75 -0.85 weaner equivalents/ha gave near-optimum gross margins with utilization of native pastures on average below the critical level of 40% utilization at which overgrazing was likely to occur (Scattini 1973). As in the previous simulation example, calculations for a single 'average' year overestimated production and gross margin compared to the average of 30 years simulation.

The model also provides output of probability distribution of outcomes and management effects based on the 30 years of daily climate data. The 'preferred' system may not be the system which has the maximum average productivity. Reliability and sustainability are important criteria in selecting the preferred system (Table 3) which will depend on the producers' attitude to risk.

TABLE 3
Productivity and reliability of combinations of stocking rate (weaner equivalents per ha of whole property, WE/ha) and % oats for Japanese ox market (580 kg/head at 42 months).

Combinations to give 580 kg LW/head	Oats	0	2.5	5	10	15	20
	WE/ha	.39	.51	.63	.76	.86	.90
Gross Margin ($/ha)		33	43	51	59	62	61
%Co-efficient of variation		34	37	38	39	40	45
% Gross margin/Livestock capital		38	39	40	38	36	33
% Utilization of native pasture		17	23	28	35	42	46

Use of model for extension and producers

The two case studies given show how the model can be used to calculate 'best' long term decisions. Such analyses would be appropriate where a producer wishes to follow a long term strategy. Properties vary in production attributes (plant production, potential liveweight gain) and climatic conditions. Where these can be estimated or measured, the model can be used to examine different enterprises for individual properties. The model can also be used for tactical studies such as changing stocking rate according to seasonal condition or prices. Simulation studies of a tactical type require formulation of decision rules e.g., adjusting stocking rate in autumn based on available feed. The model can then be used to evaluate different tactical approaches.

REFERENCES

Addison, K.B., and Rickert, K.G. (1984). Proceedings of Australian Society of Animal Production 15: 11.

Clewett, J.F., McCown, R.L., and Leslie, J.K. (1986). Proceedings of the Third Australian Conference on Tropical Pastures, (Tropical Grassland Society: Brisbane), in press.

Daly, J.J. (1983). Queensland Agricultural Journal 109: 61-97.

Evans, T.R., and Wilson, J.R. (1984). Proceedings of 10th meeting of European Grassland Federation, Norway 1984, 372-6.

Fitzpatrick, E.A., and Nix, H.A. (1970). In 'Australian Grasslands' (Ed. R.M. Moore) (A.N.U. Press : Canberra), 3-26.

Hendricksen, R.E. (1970). Proceedings of XI International Grasslands Congress, Surfers Paradise, 814-7.

Hendricksen, R.E. (1981). Factors controlling the nutritional value of Lablab purpureus (L.) Sweet cv Rongai. M.Agr.Sc. Thesis, University of Queensland, Brisbane, Australia.

McCown, R.L. (1980-1). Agricultural Systems 6: 303-17.

McKeon, G.M., Rickert, K.G., Robbins, G.B., Scattini, W.J., and Ivory, D.A., (1980). Fourth Biennial Conference, Simulation Society of Brisbane , Brisbane 1980, 9-16.

McKeon, G.M., Rickert, K.G., Ash, A.J., Cooksley, D., and Scattini, W.J. (1982). Proceedings of Australian Society of Animal Production 14: 201-4.
McKeon, G.M., and Rickert, K.G. (1984). Proceedings of Australian Society of Animal Production 15: 15-39.
McKeon, G.M., Rickert, K.G., Scattini, W.J. and White, N. (1986). Queensland Dept. of Primary Industries Information Series, in press.
McLennan, S.R., Hendricksen, R.E., Beale, I.F., Winks, L.W., Miller, C.P. and Quirk, M.F. (1985). In "Native Pastures in Queensland" editors W.H. Burrows and J.C. Scanlan (Queensland Dept. of Primary Industries: Brisbane), in press.
Milles, A.H. (1984). Queensland Agricultural Journal 110: 83-111.
Murtagh, G.J. (1980). Tropical Grasslands 14: 232-8.
Peake, D.C.I., Henzell, E.F., Stirk, G.B. and Peake, Ann. (1979). Agro-Ecosystems 5: 23-40.
Rickert, K.G., and McKeon, G.M. (1982). Proceedings of Australian Society of Animal Production 14: 198-200.
Rickert, K.G., and Winter, W.H. (1980). Tropical Grasslands 14 : 238-45.
Rickert, K.G., McKeon, G.M., Scattini, W.J., and Williams, L.E. (1985). In "Native Pastures in Queensland" editors W.H. Burrows and J.C. Scanlan (Queensland Dept. of Primary Industries: Brisbane), in press.
Robbins, G.R. (1984). Relationships between productivity and age since establishment of pastures of Panicum maximum var trichoglume. Ph.D. Thesis, University of Queensland, Brisbane, Australia.
Scattini, W.J. (1973). A model for beef cattle production from rangeland and sown pastures in south eastern Queensland. Ph.D. Thesis, University of California, Berkeley, U.S.A.
Scattini, W.J. (1981). Australian Journal of Experimental Agriculture and Animal Husbandry 21: 326-33.
White, B.J. (1978). A simulation based evaluation of Queensland's northern sheep industry. Geography Department, James Cook University. Monograph Series No. 10, pp. 109.
Wicksteed, L.T. (1980). Proceedings of Australian Society of Animal Production 13: 361-4.
Wicksteed, L.T. (1986). Proceedings of the Third Australian Conference on Tropical Pastures, (Tropical Grassland Society: Brisbane), in press.
Williams, L.E., and Moorhouse, W. (1976). Queensland Department of Primary Industries, Economics Services Branch, Miscellaneous Bulletin Series No. 6.
Wilson, J.R. (1982). In "Nutritional Limits to Animal Production from Pastures" (Commonwealth Agricultural Bureaux : Farnham Royal, U.K.), 111-31.
Wilson, J.R., and t'Mannetje, L. (1978). Australian Journal of Agricultural Research 29: 503-16.
Winks, L.W, (1975). Tropical Grasslands 9: 159-64.