TROPICAL PASTURES IN THE FARMING SYSTEM : CASE STUDIES OF MODELLING INTEGRATION THROUGH LINEAR PROGRAMMING

J.K. TEITZEL*, J.R. MONYPENNY** and S.J. ROGERS**

* Department of Primary Industries, South Johnstone. Qld 4859
** James Cook University, Townsville. Qld 4811

ABSTRACT

Computerized modelling is a powerful complement to biological research. It can integrate research results for both the research worker and research user. A range of methodologies are available and choice of model is a matter of pragmatically deciding on the most appropriate for the task in hand. We have recently developed and used a linear programming model to assist with studying the integration of new pasture systems and cattle management options for different property types in the humid tropics of Queensland.

The model was developed on a base of land class specifications which allowed the description of any property in the region. For given prices of inputs and outputs and a given desired management intensity, the model derives a gross margin maximizing solution which indicates the type and area of pasture to be planted on each land class, the number and class of cattle to be purchased and sold each month and the stocking rates and grazing patterns of each animal group. A sequential series of experimental manipulations of the model was then conducted. Production and marketing variables and preferences considered most likely to influence the productivity and profitability of cattle fattening enterprises were studied for representative property types. This resulted in the isolation of integrated long term management strategies for each property type.

INTRODUCTION

Linear programming (LP) is a powerful and widely used technique for numerical optimizing. Applications of LP to agriculture have been outlined by a number of authors including Heady and Candler (1958) and Beneke and Winterboer (1973). It was firstly and is still principally used by economists to study complex problems of cost minimization or profit maximization, although animal nutritionists have used it widely for determining least cost rations. More recently, with the availability of powerful "user friendly" LP algorithms on most main frame computers, it became possible to develop large LP matrices which have permitted realistic descriptions of biological as well as economic relationships.

A number of "whole farm" animal production systems involving grazing animals and pasture integration have now been studied using LP models : eg. Morris and Wilton (1976); Nott (1977); Bartlett and Clawson (1978); Whitson and Kay (1978); and Miller (1982). We know of only two studies (Jensen 1968; and Teitzel 1985) where LP models have been used to study the use of tropical pastures in farming systems. The study of Jensen (1968) was primarily an economic assessment. Teitzel (1985) describes the development and use of a large bioeconomic LP model to study the integration of new pasture systems and cattle management options for different property types in the humid tropics of Queensland.

THE CASE STUDY PROBLEM

The basic problem was to understand the reasons for poor adoption of new pasture technology by cattle fatteners in the wet tropical coast of Queensland (the coastal plain from Ingham to Cape Tribulation). The technology was largely based on the results of a fairly large number of conventional small plot, agronomic experiments on weed control (Bailey 1977), species evaluation (Harding 1972) and soil fertility (Teitzel 1979).

Although considered by researchers to be suitable for extension to the local industry, it was found that information provided by the experiments was considered by many to be fragmented and specific to a rather artificial set of experimental conditions. Attempts were then made to synthesise the information into a series of land-plant-animal management systems. Some of the systems were subsequently tested in long term (6-10 years) physical modelling exercises (Teitzel et al in preparation) similar to the farmlet studies of Murtagh (1980) and Bell (1976), and the full scale systems studies of Eadie and Maxwell (1975). Such exercises are expensive and time consuming; hence only a few of the systems able to be synthesised were able to be tested. Additionally, the problem of site specificity remained. Each farm has different financial considerations with different areas of different soil types with different drainage characteristics in different rainfall zones. The integration of a new piece of technology into an existing whole property management system may also be more complex than imagined by specialist agricultural scientists. For instance, agronomists may develop a new pasture type which produces more fodder of higher digestibility during a season when existing pastures are relatively unproductive. To take advantage of these improved features, a cattle fattener would have to alter his stock movement program and possibly his entire stock buying and selling policy. Such major manipulations, if not evaluated carefully, could result in financial and ecological disadvantage to the whole property management system. Computer modelling procedures are useful tools for studying such complex questions.

A wide range of computer modelling procedures are available (eg. Eck 1976) including benefit-cost analysis, linear programming, optimal control, goal programming and dynamic simulation. The use of some of these in agriculture has been described in a number of guides and reviews : eg. Dent and Anderson (1971) and Dalton (1975). The impression gained from the literature is that simulation and linear programming are the only methods capable of effectively handling the large data sets required for a realistic numerical description of the biological, physical and economic aspects of whole farm production systems.

Most of the models developed by biologists could be described as biological processes models (eg. mineral cycling, etc.). Simulation has advantages in allowing a realistic numerical description of these dynamic processes. However, the linking of all the relevant processes into a whole farm simulation model can be a cumbersome and unnecessarily detailed activity. Simulation seems to have a limited analytical capability with an inherent danger of the operator becoming bogged down in endless trial and error simulation runs. Alternatively, for the purpose of integrating management systems, modern linear programming algorithms appeared to provide a more pragmatic methodology.

THE LINEAR PROGRAMMING MODEL

Each cattle fattening property on the wet coast is an aggregate of varying areas of different land classes. Pastures are grown on these lands for grazing by store steers purchased from breeding properties in the dry hinterland. Cattle are resold when they reach the condition and bodyweight desired by the various market outlets. Thus, the properties are essentially "operating on margins" arising from bodyweight gains and finishing to a desired carcass quality.

The LP model describes, on a monthly basis, the "safe" fodder production characteristics of four pasture type options (grass/N fertilizer, optimum grass/legume, fertilized robust pasture, lightly fertilized robust pasture) which may be managed at one of three quality/growth rate options (standard stocking/high quality, moderate stocking/moderate quality, heavy stocking/low quality) on three land classes (undulating, well drained flat and poorly drained) in the Innisfail/Tully area. The four pasture categories have different species combinations with different grazing characteristics on the different land classes. These pasture options have around four fold differences in carrying capacities and eight fold differences in running costs.

The model allows options of purchasing three steer classes (weaner, yearling, ox) in any month of the year for fattening at any one of five growth rate combinations (dependent on pasture type, land class and stocking rate) to one of two body weights suitable for different market outlets (export or local butchers trade). The purchase options can be taken at any month of the year for turnoff at the available sale options or for any specified price premium situation.

An operational run of the model derives the maximum gross margin at given prices of inputs and outputs for a property having a given area of the different land classes at a given level of managerial intensity. The solution also indicates the area of each pasture type to be planted on each of the land classes, quality levels at which the different pastures are to be maintained through grazing management, the number and classes of steers to be purchased each month, the feed quality requirements and the marketing policy. Solution stability is indicated by a range sensitivity test. The quantity of unconsumed fodder in any month is indicated by a print out of slack variables. The annual productivity per hectare of individual land classes is given by the print out of dual prices.

Full details of the model, its operation and validation exercises are given by Teitzel 1985.

EXPERIMENTATION

The objective was to conduct a series of experimental manipulations of the model by varying the production and marketing variables and managerial preferences most likely to influence the productivity and profitability of a range of cattle fattening properties. The two factors which probably have the greatest influence on a beef producer's income and his selection of management strategies are beef prices and the composition and area of the different land classes found on his property. Within the over-riding constraints imposed by those two factors, cattlemen frequently impose additional constraints. Some of the most common are associated with a decision to opt for an easier life style by having a less intensive production system than his combination of resources is capable of safely attaining. The easiest way for a cattleman to do this is to choose low stocking rates. Another set of constraints are frequently imposed by a manager, when he may decide to sell or buy in replacement stock at particular times of the year. This may be done to supply fat bullocks at a period when beef prices are likely to be highest or to better co-ordinate production with likely turnoff periods from a syndicated breeding property in the dry tropics. To study the influence of these factors on the selection of optimum management strategies, the model was subjected to the following sequential series of manipulations.

1. Property area was set at a constant 300 ha but the areas of undulating (U), well drained flat (F) and poorly drained (P.D.) land classes were assigned variable groupings of 200, 80 and 20 ha to give the total of 300 ha. This gives a factorial array of six representative property types.

2. Three store cattle prices (25c, 50c and 75c/kg liveweight) were used to study the effect of variable beef prices. An additional 5c/kg liveweight was allocated to all animals sold at "export" weight. This reflects an incentive for larger producers to sell at the heavier export trade killing weights. Local butchers trade cattle were sold for the same price per kg as they were purchased.

3. The effect of a decision to opt for an easier life style was studied by running the model at the safe specified stocking intensity and 20 percent below this intensity.

4. The influence on optimum strategy selection of higher beef prices at different times of the year, was studied by runs which allocated an additional price premium of 5c/kg liveweight for any export weight cattle sold during the months of February, March, September and October. This price premium represents a situation which reflects the ability of the wet coastal area to fatten cattle for sale in these normally out of season months, thereby having the capacity to extend the killing season of the Cairns and Townsville meatworks.

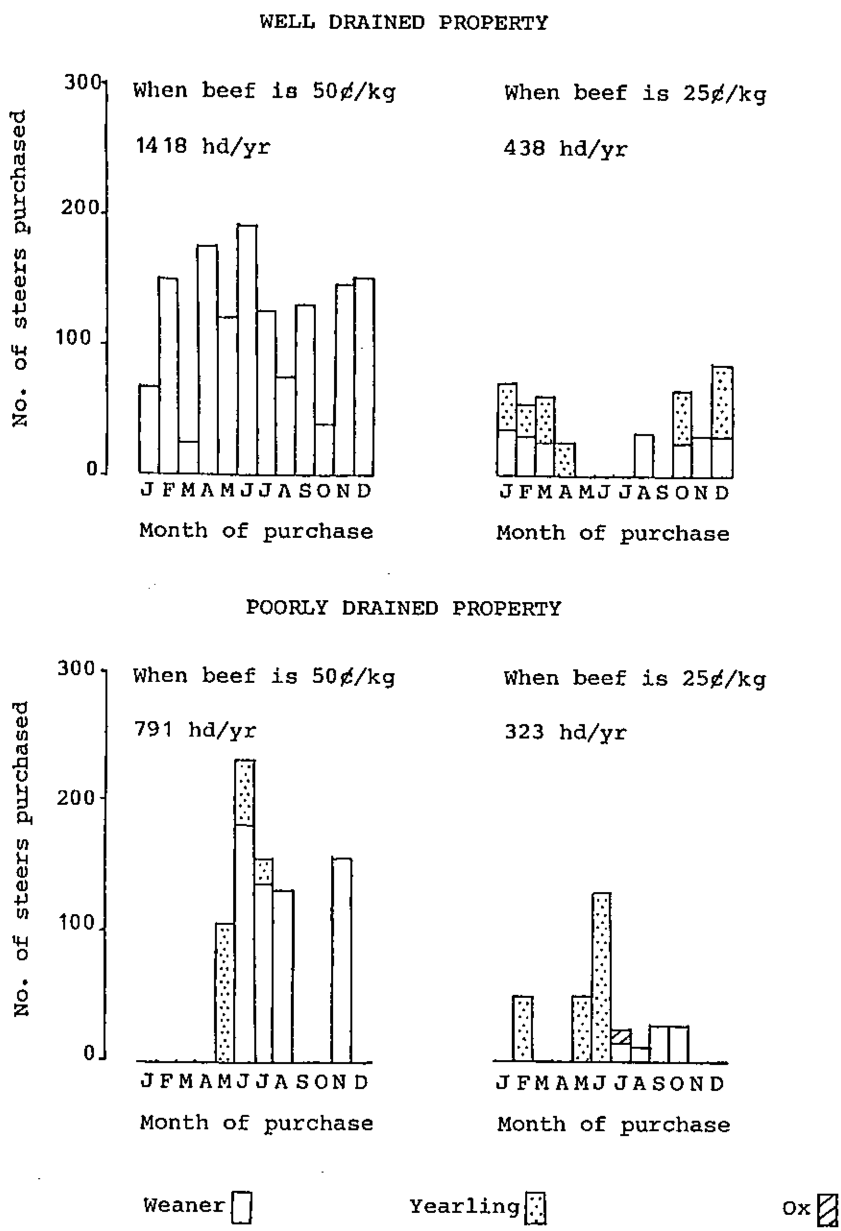

FIGURE 1

Some selected steer purchase programs

RESULTS

A small selection of the output from the experimental series is presented to demonstrate some of the integrative and analytical features of the model.

Pasture selection

The types of pasture selected for the different land classes were most dependent on manipulations of beef price and property land class structure. A greater diversity of pasture types were selected for predominantly poorly drained properties. When beef prices were around 50c/kg liveweight and above, the model selected grass/N pastures on all well drained land classes and varying proportions of grass/legume and robust pastures on poorly drained land. Below 50c/kg liveweight, the model selected different combinations of the less costly pasture types on all land classes. Sensitivity analyses indicated that when beef was 25c/kg liveweight, the running cost of grass/N pastures ($132/ha/yr) had to be reduced by $20 to $40 depending on land class before that pasture type would enter the model solution. However, even at these low beef prices, an additional (to the 25c/kg) 5c/kg premium paid at the beginning and end of the killing season, caused a model solution change to grass/N pastures on areas of undulating land on predominantly poorly drained properties. By way of contrast, when beef prices were set at 75c/kg, results indicated the price of the urea component of running costs could more than double before it became more profitable to plant grass/legume pastures on the well drained land classes.

Pasture stocking

Examples of some of the variations in the selected stocking programs brought about by changes in property land class structure, general beef prices and the payment of a seasonal price premium are shown in Figure 1. The biggest changes in stock numbers was brought about by the change in beef price from 50c to 25c/kg. In reality, this change in stock numbers is due to a selection change in pasture type from grass/N to grass/legume pastures on the well drained land classes. There were also large stock program changes associated with changes in property land class structure. The seasonal premium brought about changes in total stock numbers, the distribution of the purchase and the classes of steer purchased.

Pasture quality management and utilization

The slack variables of the LP solution indicate the monthly quantities of fodder unable to be utilized by the selected stocking program. In general, fodder surpluses increased as beef prices decreased (less grass/N pasture) and as the area of poorly drained land increased. However the poorest utilization of available fodder resulted from stocking programs selected to take maximum financial advantage from a seasonal beef price premium. These three factors also generally resulted in selection pressure for grazing programs involving heavier stocking rates and a lower fodder quality at certain times of the year.

Financial performance

Some changes in whole property and individual land class gross margins are shown in Table 1. These clearly indicate the importance of beef price and the desirability of having a property with a predominance of well drained land classes. It is also of interest that undulating land was more valuable on predominantly poorly drained properties and that poorly drained land was more valuable on well drained properties. This illustrates the model's capacity to integrate the relative strengths and weaknesses of management factors on a whole property basis.

TABLE 1
Some changes in gross margins

Predominant Property Type	Beef Price/kg		
	25c	50c	75c
Whole property gross margins ($/300 ha)			
Well drained	20282	70338	141064
Moderately drained	17656	61258	125244
Poorly drained	11308	41457	81556
Gross margins for undulating land ($/ha)			
Well drained	66	233	469
Moderately drained	68	233	473
Poorly drained	91	284	552
Gross margins for poorly drained land ($/ha)			
Well drained	38	117	264
Moderately drained	30	117	253
Poorly drained	11	69	132

CONCLUSIONS

In the case study, financially stable management systems were isolated for six property types representing a broad cross section of cattle properties found in the wet tropical coast. The exercise resulted in an improved level of understanding of problems associated with integrating alternative pasture technologies into cattle fattening systems. Additionally, the isolation of a number of important knowledge gaps led to a re-allocation of priorities for subsequent biological research. The model can be easily manipulated to describe any of the 374 holdings carrying beef cattle on the coast and is particularly efficient at synchronizing the feed requirements of the cattle options with the seasonal growth distribution patterns of the pasture options. As such, the model could be a powerful decision support system for individual cattle fattening properties.

There were, however, important limitations in the performance of the model. In particular, the incorporation of stochastic simulation and risk analysis as described by Anderson et al. (1977) would give increased realism. Such extensions could be useful in generating pasture growth data from historical climatic data (particularly wet season cloud cover, winter temperatures and spring rain) and in generating a series of beef price changes and their consequences.

Among the most widely perceived limitations of LP is that standard LP algorithms are deterministic and linear and are therefore inappropriate for studying biological systems. However, with the now fairly ready availability of very powerful LP packages, it is possible to construct LP models which approximate non linear and non deterministic situations. In the case study, although each model solution was deterministic, the results of the experimental series provide a series of moving optima, an approach which is clearly non deterministic. Additionally, individual model solutions provide sensitivity analyses of variables under management control. Similarly, although the relationship between individual data points in a LP matrix is, by definition, linear, the practical representation of non linear biological relationships is not insurmountable. For instance, in the case study, monthly cattle bodyweight changes and monthly carrying capacities of the land/pasture units were represented by a series of lines of different slopes which, when connected on an annual basis, can represent the known non linear relationships with time.

Briefly, computerized modelling is a powerful complement to biological research. The study discussed here used LP. It is a powerful tool but not necessarily the most appropriate tool for all situations. The choice of model can best be made by combining the expertise of the biological scientist who "knows what is wanted" and the expertise of the modeller who "knows what is available". Some individuals may be fortunate enough to posess both sets of skills, but for the rest of us there is profit in cooperative endeavour.

REFERENCES

Anderson, J.R., Dillon, J.L., and Hardaker, B. (1977). "Agricultural Decision Analysis" (The Iowa State University Press: Ames).

Bailey, D.R. (1977). Weed control in tropical pastures. In Skerman, P.J. "Tropical Forage Legumes" (FAO: Rome).

Bartlett, E.T., and Clawson, W.J. (1978). Journal of Animal Science 46: 812-8.

Bell, B.A. (1976). Research paper 6/76. Economics Division, Ministry of Agriculture and Fisheries, New Zealand.

Beneke, R.R., and Winterboer, R. (1973). "Linear Programming Application to Agriculture" (Iowa State University Press: Ames).

Dalton, G.E. (Ed.) (1975). "Study of Agricultural Systems" (Applied Science Publishers: London).

Dent, J.B., and Anderson, J.R. (Editors) (1971). "Systems Analysis in Agricultural Management" (John Wiley and Sons: Sydney).

Eadie, J., and Maxwell, T.J. (1975). In "Study of Agricultural Systems", editor G.E. Dalton, (Applied Science Publishers: London), 395-413.

Eck, R.D. (1976). "Operations research for business" (Wadsworth: California).

Harding, W.A.T. (1972). Tropical Grasslands 6:191-9.

Heady, E.O. and Candler, W. (1958). "Linear Programming Methods" (Iowa State University Press: Ames).

Jensen, R.C. (1968). Review of Marketing and Agricultural Economics 36: 139-48.

Miller, C.P. (1982). Systems modelling in animal production research: an interactive case study. PhD Thesis, Massey University, New Zealand.

Morris, C.A., and Wilton, J.W. (1976). Canadian Journal of Animal Science 56: 475-87.

Murtagh, G.J. (1980). Tropical Grasslands 14: 232-38.

Nott, S.B. (1977). Journal of Dairy Science 60: 464-72.

Teitzel, J.K. (1979). In "Pasture Production in Acid Soils of the Tropics", editors P.A. Sanchez and L.E. Tergas, (CIAT: Colombia), 95-108.

Teitzel, J.K. (1985). Integration of new pasture systems and cattle management options for different property types in the humid tropics of Queensland. PhD Thesis, James Cook University of North Queensland.

Whitson, R.E., and Kay, R.D. (1978). Journal of Animal Science 46: 823-30.