
VOLUME 62 2002

AN EVALUATION OF THE ROLE OF SYSTEMS MODELLING IN AN AGRICULTURAL RESEARCH PROGRAMME

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INTRODUCTION

THE USE of systems modelling in agricultural research has been advocated for some time and there is growing evidence in the literature of agricultural applications (Jones, 1970; ASAP, 1972; ARNC, 1974). As yet, few scientists in New Zealand concerned with applied agricultural research have made use of the technique.

An opportunity for scientists to evaluate the role of systems modelling in agricultural research in New Zealand was provided by a recent conference at Massey University (Drummond and Wright, 1973). Those attending concluded that modelling is generally discussed in terms of potential rather than actual benefits, and there was a lack of evidence to assist the uncommitted scientist in making his own evaluation.

In an attempt to provide such evidence, Massey University and the Ruakura Agricultural Research Centre established a joint project at Ruakura with the specific objective of exploring and evaluating the role of systems modelling in agricultural research. The project commenced in January 1975 and this paper reports on the results that have been achieved since then.

PROJECT ORGANIZATION

Intensive pastoral beef fattening systems were chosen for study as it was believed that this would facilitate progress in that the complex tasks of modelling reproduction and lactation were avoided.

The project was conducted as an inter-disciplinary exercise. The co-ordinator of the group was the only one with full-time involvement in the project, and the only one with previous experience in modelling agricultural production systems. The other members comprised two animal scientists, a pasture agronomist, a soil scientist and a computer scientist, with their level of involvement depending on the component of the model being developed, or the particular problem being studied. The organization of the project was itself an experiment which proved successful.

It was considered essential to avoid the characteristic of many modelling projects of concentrating on model development and testing, at the expense of using the model. An attempt was therefore made to allocate the available time between model development and use.

THE BEEF PRODUCTION MODEL

A detailed description of the model is being prepared for publication and is not presented here. In brief, the model simulates daily pasture and animal production in response to weather and management variables. The growth rate of ryegrass/white clover pasture is determined by time of year, temperature, available soil moisture, and accumulated level of dry matter. Details of this component have been published (Wright and Baars, 1975).

The animal component consists of two major parts, the estimation of pasture intake, and the prediction of animal performance. Pasture intake is determined by the amount of pasture per unit area and the area offered per head, using a function of the form.

$$y = a\ (1-b^{x})$$

where y is daily DM intake as a % of LW,
a is the upper limit to intake,
b is a factor representing pasture density, and
x is the amount of pasture offered as a % of LW.

In the present model a is set at 3%, and b is determined by the average amount of DM per hectare (ADMPH) on the area being grazed using the relationship

$$b = 0.85-0.00005\ \text{ADMPH}$$

The relationship (Fig. 1) is similar to other intake functions (*e.g.*, Marsh and Murdock, 1974), with the amount of pasture per unit area as an added variable.

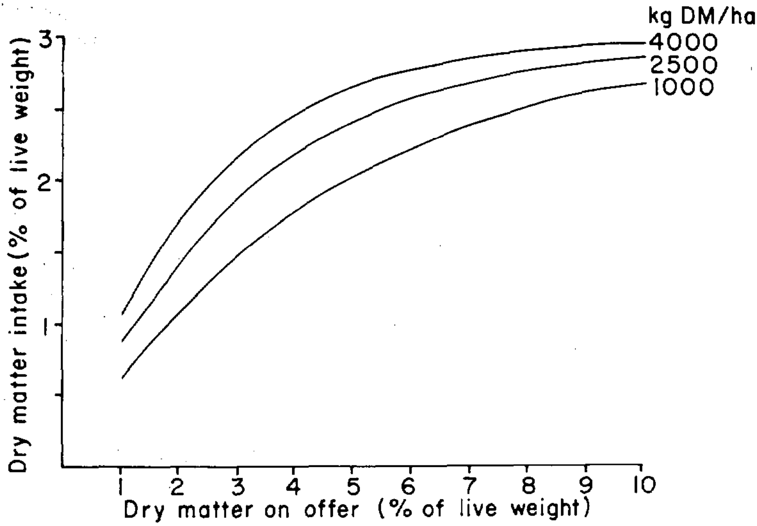

FIG. 1: *Functions for predicting daily pasture intake from pasture dry matter on offer to steers grazing pastures with 4 000, 2 500 or 1 000 kg of pasture dry matter per hectare.*

Animal performance is then estimated using the procedures described by NRC (1970).

The model allows daily shifts of up to two groups of cattle around a fixed area. Surplus pasture may be conserved and animals can be bought and sold according to time or weight. The model uses meteorological data from previous years. It may be run with predetermined decision rules to simulate the rather rigid structure of a formal experiment, or it can be used in an interactive mode with the operator making decisions as the season progresses.

TESTING AND VALIDATION

Comparisons of predicted and actual results were made for soil moisture levels and pasture production. The satisfactory nature of these comparisons is shown by the results in Fig. 2.

Similar comparisons of predicted and actual measures of pasture intake were made using data from four grazing experiments (Reardon, 1975, and unpublished). They indicated good

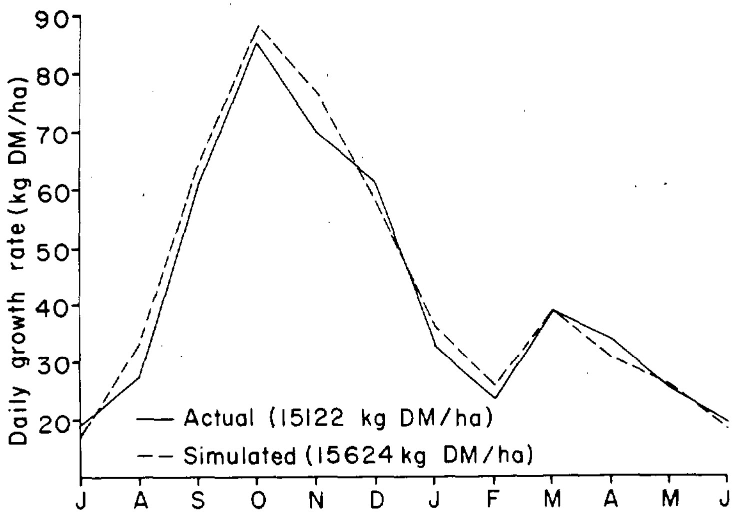

FIG. 2: *Actual and predicted daily growth rates of pasture averaged for each month over 6 years (1958-9 to 1963-4). Actual data were supplied by W. C. Weeda (pers. comm.).*

agreement at lower levels of intake and overestimates of intake at high levels. This trend is shown by the relationship

$$Y = 1.14\ X \qquad (\text{RSD} = 0.31)$$

where Y is the predicted and X the actual daily dry matter intake as a percentage of liveweight (mean X, 1.70).

Testing of the system as a whole was limited by the scarcity of comprehensive data from real systems. In addition, the model does not allow for the effects of insects and disease on pastures, or those of metabolic disorders and parasites on animal production. Consequently it is difficult to interpret differences between output from the model and real systems. For example, in one experiment it is known that pasture production was affected by insect damage. As expected, the simulated results were higher than the actual results and the comparison was of little value as a test of the model.

Acceptance of the model as a whole was based on the results of such testing as has been possible, and a subjective assessment of results such as those given in Table 1. The validity of the

TABLE 1: SUMMARY OF SIMULATED PRODUCTION DATA FOR A BEEF FATTENING SYSTEM

	Jul.	*Aug.*	*Sep.*	*Oct.*	*Nov.*	*Dec.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*Jun.*
Rainfall (mm)	147	116	72	85	86	85	59	8	64	71	152	106
Daily pasture growth (kg DM/ha)	17.5	23.6	57.1	89.2	69.1	72.4	41.7	0.6	10.9	22.0	27.0	22.1
Pasture level (kg DM/ha):												
Mid-month	1365	1097	1495	2364	2460	2463	2061	1161	675	923	1225	1324
Pre-grazing[1]	1820	1665	2265	3400	3000	3210	2260	1113	1000	1610	1845	1742
Post-grazing[1]	670	688	1155	2090	1662	1790	1140	604	725	730	810	716
Utilization (%)[1]	63	59	49	39	45	44	50	46	27	55	56	59
Stocking rate/ha	7.5	7.5	7.5	7.5	7.5	7.5	6.2	3.8	0.8	7.5	7.5	7.5
Liveweight (kg)	242	251	267	299	340	377	400	406	408	180	182	188
Liveweight gain (kg/day)	0.28	0.27	0.78	1.35	1.33	1.10	0.81	0.50	0.81	0.00	0.16	0.23
Daily pasture intake (kg DM)	3.6	3.6	5.3	8.2	9.3	9.9	10.1	8.2	9.8	1.6[2]	2.7	3.1

[1] On last day of month.

[2] Silage in addition at 1 kg DM/head/day.

Total pasture production = 13 875 kg DM/ha
Net liveweight production = 1 487 kg/ha
Total liveweight sold = 3 186 kg/ha

model requires reassessment for each proposed use. It is expected that feedback from well monitored experiments that are in progress or are planned will either increase confidence in using the model, or indicate areas where further development is necessary.

PROJECT EVALUATION

It is emphasized that this evaluation is primarily by scientists who have not previously used or been involved with systems modelling. Their experience in using the model was confined to the four months remaining after model development and consequently specific examples of use of the model are limited. Each simulation was dependent on thorough analysis and evaluation of previous simulations. This proved to be time-consuming and as a consequence determined the rate of progress. A more comprehensive evaluation clearly requires further experience with the technique together with feedback from experiments in the field. Despite these limitations there is unanimous agreement amongst those involved that the project demonstrated a number of roles for systems modelling in agricultural research.

THE INTERDISCIPLINARY APPROACH

A major achievement was the promotion of interdisciplinary communication and co-operation. The project encouraged members of the group to learn outside their particular disciplines, and provided a focal point for the interchange of ideas and the development of co-operative work. That this is recognized as a significant contribution is believed to be a reflection of the current organization of research into largely separate, specialized categories. It is recognized that systems modelling is by no means the only way of improving communication and co-operation, but it does encourage this to be done in a quantitative and productive manner.

AN AID TO LEARNING AND UNDERSTANDING

The project has been successful in developing individuals' knowledge of the components of a beef production system, and their understanding of the functioning of the system as a whole. The model has served as a framework for assembling knowledge, and, more importantly, has been a means of evaluating this knowledge in the context of a dynamic operative system.

For example, it is commonly accepted that maintenance requirements may be higher for the grazing than the housed or lotfed animal. The impact of differences in maintenance requirements on a beef production system is less well understood. It was examined by simulating a grazing experiment over two successive years, first with animal requirements as given by NRC (1970) and secondly with maintenance requirements increased by 10%.

Some of the effects (Table 2) such as those on liveweight gain and feed conversion were anticipated. Less expected were the effects of the higher maintenance requirements on pasture production. These resulted from a complex sequence of events in-

TABLE 2: PERCENTAGE CHANGES, RELATIVE TO THE NIL CONSERVATION TREATMENTS IN TABLE 3, IN SIMULATED PASTURE AND ANIMAL PRODUCTION AS A RESULT OF A 10% INCREASE IN MAINTENANCE REQUIREMENTS

	Year 1	*Year 2*
Pasture production	+ 3.6	+ 0.7
Liveweight gain	— 7.9	— 11.9
Liveweight sold	— 0.5	— 5.3
Feed conversion ratio	+ 13.5	+ 14.3

volving in the first year lighter animals grazing pasture less severely in winter and spring and more unfinished animals being available to cope with the increased DM available during autumn. In the second year, the pastures again benefited from less severe grazing in the winter and spring but the delay in finishing the lighter animals drastically reduced pasture growth during the dry summer that followed. The overall effect was higher pasture production in each year (Table 2).

By simulating a system for a wide variety of conditions, the scientist can develop a "feel" for it which is normally only obtained after many years' experience in the field. The value of this learning process to the individual is difficult to illustrate, but it is apparent that the benefits will be greatest for the inexperienced scientist. Conversely, although the experienced scientist may make the greatest contribution towards developing a model, the value of the exercise to him may be less.

Relationship between Component Research and the Whole System

It has been claimed that systems modelling can fulfill a valuable role in terms of

(1) Identifying deficiencies in existing knowledge and assessing the importance of these deficiencies.

(2) Aiding the definition of component research that is relevant to the whole system.

(3) Assessing the value of existing and proposed component research.

(4) Defining those measurements necessary to relate the whole system to component research.

At this stage the project has generated specific illustrations for only some of these aspects.

The project has emphasized that present information is insufficient to define the relationships between pasture DM offered and intake, and between pasture growth rate and total DM present for a range of pasture types and regions. In both instances, appropriate functions had to be synthesized. Radcliffe (1974) has described the shortcomings of the nationwide trials for measuring rate of pasture growth but the demands of the modelling project highlights the need for a reassessment of these trials, and has led to the establishment of a pilot trial examining alternative techniques.

Identification of "Best Bet" Systems for Field Testing

The model was used during a general investigation of production systems as a means of identifying superior systems for future field testing, and for generating hypotheses. An example of this is an investigation of different feed conservation policies in a traditional beef-fattening system. While conservation is widely practised, there are few measures indicating that advantages accrue in terms of either increased animal production or profitability. Consequently, a comparison was made of no conservation and conservation of spring surpluses as silage for subequent feeding in the autumn. Individual paddocks with more than 3500 kg DM/ha were harvested for silage as they became due for grazing in October and November provided that the average pasture level exceeded 2000 kg DM/ha. An experiment was simulated using actual meteorological data for a 3-year period so that any cumulative effects would become apparent. The stocking rate was 7.5/ha and the last 2 years included summer droughts. What differences were apparent (Table 3) favoured no conservation.

The explanation of these effects appears to be associated with improved utilization of pasture in the spring and early summer, and higher pasture production in the summer. A detailed explanation is not necessary in the present context. What is important is that this has illustrated to the group that, in attempting inter-

TABLE 3: SUMMARY OF SIMULATED CONSERVATION EXPERIMENT

	Years					
	1		*2*		*3*	
	C	*NC*	*C*	*NC*	*C*	*NC*
Rainfall (mm)	1 473		1 048		970	
Pasture production (kg DM/ha)	15 451	15 570	13 875	14 139	12 441	12 599
Area conserved (%)	50	—	10	—	60	—
Liveweight gain (kg/ha)	1 896	2 100	1 487	1 553	1 401	1 405
Liveweight sold (kg/ha)	3 261	3 289	3 186	3 266	2 741	3 034
% of animals > 420 kg LW when sold	100	100	73	100	0	32
DMI/kg liveweight gain (kg)	8.0	7.4	9.4	9.1	8.3	9.1

C Conservation
NC No conservation

pretation of the results, the data can be examined, various possibilities considered, and hypotheses generated without a real experiment having been carried out.

Aid in Definition of Treatments

The results of the comparison above are preliminary. The next stage is to use the model to simulate results for a larger number of years covering greater climatic variation, and for various stocking rates and conservation policies. This has not been done. A decision at this stage as to whether the hypothesis should be tested in the field is therefore not advisable. It is anticipated that this exploratory phase will assist greatly in definition of the treatments and decision rules appropriate to any subsequent field experiment.

The model has already been used in this regard for an experiment originating outside the modelling group. The experiment involved a study of grazing systems based on the leader/follower principle, and the indvidual treatments had been tentatively defined. The model was used to simulate a complex factorial experiment for a range of years, and examined the effect of varying stocking rates, proportion of animals in the leader group, time of splitting into groups, transfer of animals between groups, and cattle selling policies. The results led to a modification of the original proposal and the scientist concerned was of the opinion that the exercise had been useful.

In a similar manner, a modified version of the model is being used at present to study alternative irrigation policies for two Waikato soil types.

SUMMARY AND CONCLUSIONS

The project was established to answer the question: Does systems modelling have a role to play in applied agricultural research and, if so, how valuable is its contribution?

A number of roles which can be illustrated by real examples from the project have already been considered and include:

(1) The provision of a focus for an interdisciplinary approach to production research.

(2) A mechanism for integrating diverse knowledge both within and between specialist fields which helps, and indeed forces, individual workers to understand the functioning of the wider agricultural ecosystem.

(3) An exploratory tool in examining alternative agricultural systems with a view to identifying those that might best be examined in field experiments.

(4) An aid to deciding on experimental treatments and decision rules once a field project is decided on.

A number of additional roles for modelling in a research environment have been suggested by this project, but, as yet, have not been examined in practice. These are:

(1) To assist in decision-making during the running of a field experiment.

(2) To aid the inexperienced or specialist scientist in obtaining an appreciation of the results of management decisions in a dynamic and interactive agricultural production system.

(3) To assist in the transfer of information from research to advisory officers and vice versa.

(4) To aid decision making by the administrators of agricultural research.

None of these roles is unique to modelling; each has been capably filled by individuals; occasional individuals have fulfilled all roles. The contribution of modelling is not in doing something new, but in facilitating existing processes of integration and decision-making.

Evaluation of the roles that modelling can play is much more difficult than their enumeration. The group's evaluation is perhaps best summarized by its unanimous recommendation that systems modelling be developed at this research centre as an aid to those engaged in applied agricultural research.

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