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COMPUTER MODELS AND THE STUDY OF GRAZING SYSTEMS

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INTRODUCTION

In simple terms, a computer model of a grazing system is a series of mathematical equations, arranged by a model builder, to mimic the complex processes of the system. A computer quickly processes the equations and in doing so transforms input data (e.g. rainfall) supplied by the user, into useful information (e.g. animal production). Thus, a model has been defined as a collection of hypotheses that express the operation of the system in mathematical terms (Rose 1973). It is also a simplification of a real-life system that has been designed for a specific purpose.

Computer models of agricultural systems were developed and promoted with enthusiasm during the 1960s and 70s (Van Dyne and Abramsky 1975). They analysed the components of a system, and complex interactions between components, in an objective and quantitative manner. However the capacity of these early models to solve practical problems was limited and the initial enthusiasm for modelling was replaced by caution among some model builders and organisations funding research (Bennet and Macpherson 1984). The early models often emphasised a comprehensive biological description rather than the needs of potential users. Lessons from the early models, together with the rapid increase in availability and power of computing facilities have influenced a new generation of model builders. Today government agencies are supporting a wide range of modelling projects as aids to managing agricultural systems (Morley and White 1985). This address focuses on computer models of grazing systems and illustrates the benefits that research workers, farm advisors and farmers might gain from the models.

TYPES OF COMPUTER MODELS

The type of computer soft-ware used in a model provides a convenient basis for classification.

Spreadsheets

Spreadsheet models are powerful and convenient tools, well suited to financial analyses (Woodford 1985) or to simulating restricted grazing systems (Morley 1987). Equations are arranged in logical sequence and are readily examined and changed. The tabulated output is often supported by a graphic display. Anyone of several spreadsheet languages can be used but distribution of such a model is constrained by a potential user needing the spreadsheet language on which a model is based. Also, compared with a dynamic simulation of the same grazing system, a spreadsheet model could not process large scale data files such as long-term weather records, nor estimate year-by-year variability in production (Rickert and McKeon 1988). In spite of these limitations, the relative simplicity of a spreadsheet model makes it a useful introduction to a more complex dynamic simulation model of a grazing system.

Linear programming (LP models)

LP models have been widely used to determine the optimum combination of factors to achieve a specified goal. Devising the least-cost ration that meets a specified nutrient status from a variety of feeds is a classic role for linear programming. Advanced versions of linear programming, often called mathematical programming, have been used in models of beef cattle on tropical pastures (Teitzel *et al.* 1986) and for farming systems based on crops and sheep in Western Australia (Kingwell and Pannell 1987). Output from LP models is deterministic and links with dynamic simulations may be necessary to give a probabilistic analysis of management options.

Dynamic simulation

Dynamic simulation models (DS) estimate the status of components in the system, by processing input data for specified time periods, such as daily rainfall. The input files may be very large (e.g. 100 years of daily rainfall) with the procedural languages (FORTRAN, PASCAL or BASIC) commonly used for DS models. Since the output reflects the system's response to natural variation in the input data, DS models may provide probabilistic analysis of the performance of a system. This is a valuable attribute of DS models. For example, McKeon *et al.* 1986 showed the benefits of using historical weather records as input in a model for grazing systems in southern Queensland. When average weather was used instead, beef production was overestimated, particularly at high stocking rates, because the influence of drought years on production was ignored.

Because of the above features, DS models have been widely used for the simulation of grazing systems (McKeon and Scattini 1980). However, most DS models have been built by researchers for researchers. They were not directed towards the problems that extension officers or farmers perceived to be important, nor were the models accessible to these persons. This unfortunate situation contributed to the poor reputation of DS models that was mentioned previously.

Expert systems

Expert systems, as the name suggests, attempt to mimic the thinking processes used by a human expert in a topic. When such models focus on crop or pest management they are valuable aids to agricultural extension and farm management (Jamieson 1984). PROLOG is a suitable language for expert systems.

ROLES FOR COMPUTER MODELS

Research

The DS model by Vickery and Hedges (1972) provides an early example of the benefits of modelling to research. They simulated pasture and wool production at Armidale from inputs of climatic records and characteristics of the pastures, soil and flock. The model was based on results from a number of grazing trails. The model had deficiencies; the influence of the grazing animal on pasture growth was not adequately described; performance from different classes of sheep was not estimated; and aminal production was strongly dependent on the accurate prediction of digestibility of the diet selected. Thus, the model was a tool in a research program that integrated and extrapolated results from several experiments, identified critical components and interactions in the system, and identified deficiencies in knowledge. Other models have provided similar benefits (McKeon and Scattini 1980) giving rise to the view that modelling is 'a repository for conclusions from traditional research and a precursor for new research' (Ebersohn 1976). Innis (1972) took the view that modelling provided a frame of reference for research by forcing the rearcher to think about the whole system. Together these reports show that modelling provides insight, understanding and direction in some research programs. It is a tool for supporting research that need not benefit persons outside the research program.

Extension

Farm advisors need to apply new information that may modify existing farming practices in technical, managerial or economic terms. They gain confidence in their recommendations through a careful assessment of new information tempered by local demonstrations or experiences. Problems arise when a drastic change to a grazing system is proposed but local experience with the new technology is limited. In this situation a DS model can be a valuable aid to making recommendations as illustrated by the model of a shallow storage irrigation system in north western Queensland (Clewett 1985). Field demonstrations had shown that run-off water from Mitchell grass pasture could be collected in a shallow gully dam and used to irrigate grain or forage sorghum. The irrigated forages could then be sold or fed to livestock in the dry season. Although the new technology was demonstrated successfully for 10 years, it involved a drastic change from the traditional grazing system and a large investment in capital. A more thorough, long-term evaluation was needed before the technology could be extended on a regional basis with confidence. A DS model was constructed to predict run-off, crop yields and economic returns from long-term weather records and catchment characteristics. The model showed the technology to be unreliable because of a high likelihood of crop failure through insufficient run-off irrigation. Thus, the probabilistic analysis of long-term predictions from the model were contrary to results from the relatively short-term field study which coincided with a decade of wet years. The model prevented a regional extension program based on an unsound premise and local farm advisors could reject the technology with confidence. This example illustrates a major benefit of DS models in extension: new technology can be tested without a major financial commitment by farmers (Rickert and Ebersohn 1984).

Farmers

Farmers continually make managerial decisions of a tactical or strategic nature that involve a wide range of interacting factors. Specific goals vary widely between individual farmers, but a preferred management option for a farmer can be identified in terms of its relative productivity (which includes profitability), reliability and sustainability. Models can help in selecting a preferred option as the following 2 examples illustrate.

CAMDAIRY is a tactical model (Hulme *et al.* 1986) for dairy farmers. After specifying the cost and quality of the available foodstuffs, herd characteristics and production targets, the model calculates the least-cost ration. It assesses options in response to changing conditions such as grain prices, pasture quality or herd structure. Tactics can be evaluated.

PROBE is a model that evaluates feeding strategies for beef farmers in south east Queensland (McKeon *et al.* 1986). After specifying location, soil characteristics, herd characteristics, prices and forage sequence (type, area and grazing management of forages) the model calculates the year-by-year production of the system. Thus, reliability of the system can be estimated and a farmer can select a preferred option in relation to his attitude to risk and supply of capital, labour or machinery. Importantly, a user can observe how sensitive the system is to changes in a component, such as rainfall, prices, stocking rates or area of improved pasture. Strategies can be planned.

Teaching

In the examples above, each model provided greater understanding through intergrating components of a system in a quantitative manner. this major attribute of simulation models suggests that they would be useful teaching aids in schools. Since 'good' models are based on 'good science', teaching exercises could be devised that guide a student towards understanding the basic provesses in a system and their interactions. A student could also use a model to answer 'what if' questions in similar fashion to a farmer testing management options. Coupled with modern communications, the models could be used as teaching aids for remote areas in external-study courses.

To date computer models have not been widely used in agricultural colleges largely because of the lack of suitable computing equipment, untrained teaching staff, and lack of suitable models. These problems are now declining and models are likely to become common aids to teaching principles of pasture and animal production and management.

ATTRIBUTES

Validity

Since a model is a simplification of a real-life system it cannot mimic all possible situations. A model builder should state the inherent limitations in a model and test the hypotheses in a model by a procedure called validation.

In practice a valid model not only implies that the mathematical expressions truthfully represent the various processes in the model but also that parameters and input data are correct. These conditions rise the GIGO law of modelling: 'garbage in, garbage out'. Commonly the user must ensure that the input data are correct and that the model operates within the constraints specified by the builder.

Sometimes the builder of a model maintains contact with its users. In this way a model can be modified in response to field experiences and validation is an ongoing process.

Versatility

A useful model must be 'user friendly' towards persons who are unfamiliar with both the model and computers. It should be easy to operate, have clear documentation and error detection, and have data storage and output facilities. Models of grazing systems should also cope with a range of management strategies, have optional starting points, operate at an individual farm level and generate estimates of the productivity, reliability and sustainability of management. Achieving these qualities is helped by using modern simulation languages and standard components in model construction (Weber *et al.* 1987).

Availability

Potential users must have access to the model. Most commonly, a model is distributed to users on a disk for a micro-computer. This allows anyone with a suitable computer to use the model, but after-sale service is difficult. Alternatively, a main-frame computer can be used through a network of remote terminals. This method may restrict the number of potential users but it allows the model to be developed and used concurrently. In both cases a user may incur costs in either buying or using the model.

CONCLUSIONS

Computer modelling of grazed systems is an aid to decision making. It has been particularly useful in integrating and assessing information from, and in providing direction to, research programs. It has been less beneficial to farmers and extension officers but this is likely to change as a new generation of models come on-stream. These models will enable farmers to evaluate complex management options with added confidence. To be successful in this primary role the models need to be valid and the user needs to be 'aware' of computers and the models. Awareness will come through using the new technology. Therefore agricultural colleges should train the farmers and extension officers of the future in using the models. In doing so the models will be a valuable aid to teaching the basic biological and managerial principles associated with the system represented by the model.

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