

DISCUSSION ON GETTING MODELS OFF THE GROUND

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The papers presented within this section of the symposium were more broadly based than the section title suggests. Also the discussion in this section frequently covered more detailed aspects of model building. The major points covered in discussion were linear programmes, objective function, teamwork, model complexity, data acquisition, interactive modelling and validation.

(a) *Linear programmes*

The opinion that linear programming was only marginally connected with getting models off the ground was expressed. This was based on the view that (a) linear programming techniques are "off the ground" and (b) the techniques are already in widespread use and are well established. They may be useful as a first step for people commencing modelling, and have advantages in that little knowledge of programming or mathematics is required before running a linear programme. A major disadvantage was that only the optimum (and not near optimum) solutions are obtained.

Linear programming can be useful in several situations, e.g. least cost feed mixes, maximizing profit from a farm enterprise. As the objective function is usually expressed in dollars and cents, its use in the examination of biological systems has been limited. A further limitation of linear programming is that all constraints must be linear, and this may not apply in biological systems. In conclusion, the use of linear programming is restricted though in some circumstances it can be quite useful.

(b) *Objective function*

The question of multiple goal objective functions was raised. As the objective function must be a sum of units of the same dimension the conversion of differing inputs and outputs to the same dimension must occur before an objective function can be defined. This may not always be satisfactory, e.g., the expression of a factor such as pain in dollars and cents is (a) difficult and (b) varies widely between individuals. The value judgments which may be included in the objective function may make it a value which is at times best expressed with an associated variance.

(c) *Teamwork*

Perhaps one of the most pertinent points to emerge from discussion was the need for teamwork. The individuals in the team must have a broad knowledge of the other members' disciplines in order for communication to be effective. This will also act as a brake on individuals in the team developing their section of the system to a degree which is out of perspective with the remainder of the model. Teamwork should start when planning to collect data as the services of a programmer then may make the modelling process more efficient.

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(d) *Model complexity*

The simplest relationships which are compatible with the data and/or theory should be used in the model. The use of complicated equations, where the parameters estimated may have questionable biological relevance, increases the dangers of extrapolation. The danger exists of developing the best known sections of the model with the greatest detail. Complex equations developed from the well known section may have no more relevance than simpler equations, given the overall crudeness of the model. For example, detailed modelling of photosynthetic processes may have little relevance in a herbage intake model.

(e) *Data acquisition*

Data acquisition is one of the preliminary steps in the construction of a model. The system described used punch tape output. In some circumstances an on site computer may be more efficient; this has become increasingly attractive with the decreasing prices of computers. In any case, the data acquired are only as accurate as the sensors available. Where no suitable sensors exist, alternative methods of data logging must be used.

(f) *Interactive modelling*

CSMP enables a digital computer to be used in an analogue manner. Because a digital computer is used, some advantages of analogue computing are lost, but others are gained. Advantages of CSMP are (a) the programme can be entered easily, (b) no problems of scaling exist and (c) because of the time sharing facility more than one person may use the CSMP system at one time. However, the facility is not widely available. CSMP is most useful for small programmes and model development in the early stages.

(g) *Validation*

The theoretical reliability of using a series of equations, each with their own errors, into a model has not been satisfactorily explored. Therefore, even if a good correlation exists between predicted and observed values the reliability of a prediction outside the limits of observation is still doubtful. Validation is a critical aspect of modelling.

No discussion on optimization took place.