MODELS AND DECISION SUPPORT: BRIDGING THE MODEL GAP

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Summary. Crop simulation models were originally developed by scientists to test their understanding of the biophysical processes that contribute to crop growth and yield. They can explain a large part of seasonally-induced variation in yield. But this by itself does not justify their role in decision support at farm-level. Farmers also use models which are largely intuitive, but which often find expression as rules of thumb. These can also transform rainfall into predictions of yield for their location, and can do many other things as well. There are other kinds of models, which are simpler than crop simulation models but more explicit than the intuitive models of farmers. These can be used to negotiate some common ground between researchers and farmers, with a view to changing the behaviour of both groups.

INTRODUCTION

In recent years, a variety of crop simulation models have been packaged and promoted as decision support products intended to improve the management of agricultural production systems. In Queensland, the best known of these is WHEATMAN (7), which is a database of output from a wheat crop simulation model. WHEATMAN was originally used to highlight the issue of frost risk in wheat, and its management through the selection of appropriate cultivar and planting date combinations. It now addresses many other issues including fertiliser use, wild oat control and disease risk.

Computerised decision support packages have not been widely adopted by producers and their advisers. In an evaluation workshop conducted at Dalby in 1995, we found that, although 50% of the twenty participants owned computers, not one of the producers had used WHEATMAN. We are not suggesting that decision support systems like WHEATMAN have failed to have an impact: there has been a good deal of learning surrounding their development. But it does raise the issue of whether a computer-based model in the hands of farmers is the best way to bring about change in farmer behaviour.

The case for developing computerised decision support systems based on crop simulation models has, in part, developed around the need to address declining resources devoted to extension with cheaper and *more objective* information delivery. It is firmly rooted in the transfer-of-technology (TOT) paradigm, which views farmers as recipients of research information. It fails to take into account and value the understandings and models of farmers, and the importance of negotiation and communication in finding better ways of farming.

The current investment of R&D funds in the development of decision support products is substantial. For example, GRDC currently invest $1 million annually in the development and promotion of computerised decision support products. It is therefore timely to review where these products are likely to have their greatest impact and how other approaches might be used, in conjunction with the models of professional science, to produce more substantial benefits for the farming community. In order to do this, it is important to appreciate the relative strengths and weaknesses of scientists' models and farmers' models.

GOOD AND BAD MODELS

Casti (1) has proposed that good scientific models are *simple, accurate* and have *explanatory power*. These appear to be desirable traits for all models, irrespective of whether their origin is scientific, or based on the practical experience of farming. But there is no absolute scale against which to judge these qualities: the degree to which models meet these requirements is always related to their purpose, and there are invariably some trade-offs (2).

Simplicity

The best scientific model is the simplest that agrees with the observations. Complexity should be introduced sparingly in order to obtain better agreement with observations. Even then, the complexity needed depends on the scientific purpose of the model. Simpler models contain fewer *ad hoc* assumptions than more complex models, yet still provide an adequate account of the observations.

A farmer's model will generally be simple and can often be expressed as a rule of thumb - for example, *only plant dryland cotton if the soil is wet to three foot.* Farmers' models are focussed on action, not necessarily understanding. Their models do not attempt to explain the dynamics of soil water movement in the soil, and losses through run-off, deep drainage and evapotranspiration; that is not their purpose. Their simplicity ensures that they are transparent and therefore open to challenge, negotiation and change.

Crop simulation models, which incorporate functions describing the dynamics of soil water, crop growth and yield formation, were frequently developed to test the scientific understanding of the underlying processes. If all the understandings and interactions are captured within a model then it is possible to test their adequacy as a whole by running the model and comparing its output (e.g. yield) with observed values. A good agreement does not prove the correctness of the underlying process understanding, but a significant departure of *predicted* from *observed* demands that at least some parts of the model be modified and/or new understandings be developed. It is therefore unlikely that a model developed for the purpose of testing scientific understandings will be simple: its complexity will reflect the depth of the process understandings being tested. We need to appreciate the implications of this before advancing scientific models as the foundation of computerised decision support for farmers.

Accuracy

Accuracy refers to good, but not necessarily perfect agreement between model predictions and observed data. Accuracy can be adequate at one level of understanding but inadequate at a deeper level. So, again, the standards for accuracy depend on purpose. The quest for accuracy makes its own demands on model structure: there is a tendency for crop simulation models to become increasingly complex to achieve greater accuracy.

The standards of accuracy required also depend on whether the model is to be used to look back to review past performance, or to look forward for planning purposes. Scientists want to understand and explain what has happened in the past, but farmers (and their advisers) want to find new and better ways of doing things in the future. A model that incorporates seasonal effects to account accurately for past performance may not be particularly useful for management when there is so much uncertainty about seasons in the future. While a model that adequately explains seasonal effects can be used to quantify the probability distribution of outcomes in the future (assuming that past weather is a good guide to the future), the specification of this distribution is only valuable if it leads to changed action and better outcomes.

Explanatory Power

Casti (1) does not use explanatory power in the statistical sense - viz. the degree to which regression equations account for observed variation. Rather, he refers to the extent that a model reveals the important components, and the connections between them, within the natural system. Transparency is a necessary, but not a sufficient condition, for explanatory power; the components and connections revealed must also be important for the purpose. Transparency and high explanatory power are vital ingredients if models that are to be used to bring about change. This is because a model used for this purpose must show the important components and relationships that can be managed to produce better outcomes. A model that is transparent is obviously more powerful in creating a case for change because the logic is accessible and can be introduced as part of the case for change. Crop simulation models often lack transparency and explanatory power for all except those intimately involved with their construction. Building these models is a useful and legitimate scientific activity since these models can produce scientific insights that were previously hidden.

Farmers could conceivably use crop simulation models to discover (uncover) which processes are important, and how they might be manipulated (e.g. increasing the nitrogen supply). They could do this by repeatedly running a simulation model (doing experiments) to ascertain the relationships between inputs (usually the ones over which they have control), and outputs (most importantly, yield). But this is unlikely to be an efficient and effective means to bring about change unless the simulation effort is focussed on issues that farmers recognise as limiting their performance.

SOME EXAMPLES

French and Schultz (3, 4) proposed a model of yields of dryland crops based on a linear relationship with the available supply of water (growing season rainfall plus stored in the soil at sowing). This simple model has been used widely in southern Australia to highlight the potential gains from reducing soil evaporation (the intercept component on the x-axis) and increasing water use efficiency (the slope component). However, it does have one major deficiency in that it fails to account for the timing of rainfall events which can be critical for crop growth in many Australian environments (5). Crop modellers therefore argue that while there are significant relationships between water use and yields, in north-eastern Australia these relationships are inferior in explaining yields to those based on a crop simulation models which integrate scientific knowledge of how the system works (5).

While crop simulation models which account for the detail of seasonal effects often have higher (statistical) explanatory power, this is largely irrelevant to managers who, as yet, do not have access to sufficiently detailed seasonal forecasts to exploit this power. The counter argument is that close agreement between *predicted* and *observed* is necessary to gain credibility and acceptance of these models by farmers.

A variation of the French and Schultz approach, based on the concept of water use efficiency, combines a knowledge of stored soil water and expectations of rainfall, to calculate target yields. Other rules of thumb can be used to determine the quantity of nutrients (e.g. nitrogen) required to achieve these target yields (6). We need to make the case that a more elaborate model, which accounts for the timing of rainfall in the past, can lead to better decisions and outcomes than a simple one based on water use efficiency and target yields. This is not self-evident.

Farmers have models too. Some of these are intuitive while others find their expression as rules of thumb. When presented with series of rainfall charts or graphs, most farmers have little difficulty in spotting the planting opportunities, and their intuitive knowledge can generate yield predictions which capture the main effects of rainfall quantity and timing. Farmers' models can be used to produce yield probability distributions that resemble those generated by scientists' crop simulation models.

The worth of a model cannot be judged statistically: the notion of *better* incorporates simplicity and explanatory power, as well as accuracy, for a particular purpose. Farmers' and scientists' models are incommensurable except in the context of a purpose.

DISCUSSION

Crop simulation models are powerful tools for scientists to describe the biophysical aspects of crop productivity. Farmers are managing the same biophysical system but their need for understanding is different to that of the scientist. Farmers are managing this system within the context of a whole farm in order to generate an income. The context may also include acceptance within the community, the need to generate cash flow to satisfy the bank manger, and the need to manage a business within family relationships.

Scientific models can be used to modify and develop the models and rules of thumb of farmers. But there is clearly a need for farmers and scientists to negotiate the implications for practical action that flow from their respective perceptions. The information that is embedded within scientific models by itself does nothing to improve outcomes for farmers: it only has meaning, with potential to change actions, through people. To achieve change we need jointly-owned models which support communication and the sharing of experiences between scientists and farmers. A variety of models may be needed to bridge the cultural gap between scientists and farmers, so that each group can appreciate, affect and be affected by the perceptions of the other.

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