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Forum

The Place of Expert Systems in Agricultural Economics

David J. Pannell*

The relevance of expert systems in agricultural economics research and extension is examined. Some of the limitations of existing expert systems are described. Expert systems are useful for storing and retrieving knowledge and for solving diagnostic problems but not for mathematical optimisation. The common method of handling uncertainty in expert systems is shown to have a dubious theoretical basis. Expert systems have no facility for sensitivity analysis. It is concluded that expert systems are unlikely to replace traditional analytical tools for the solution of economic problems but that they may be useful for creation of user-friendly program interfaces.

1. Introduction

As the most successful product of research into so-called "artificial intelligence", expert systems have received considerable attention in computer magazines, mathematics and software journals, and even the popular press. Four papers describing expert systems and their application in agricultural pest management were presented previously in this *Review* (Bishop *et al.* 1987, Colomb 1987, Hearn 1987, Norton 1987). My purpose in this note is to address some of the issues glossed over or not raised in those papers, and to correct some apparent misconceptions about expert systems. The following discussion focuses on the strengths and weaknesses of expert systems, the types of problems for which an expert system might be useful, and whether they have a role in agricultural economics.

2. Expert Systems in General

Given their high profile and association with "artificial intelligence", it is easy to get the impression that expert systems are intelligent in the sense that the problem posed need not already have been solved outside the expert system. However, this is not the case. McKinion and Lemmon (1985, p. 38) observed that:

> the problem to be dealt with must . . . have at least one expert on the subject who has solved the problem. That is to say Expert Systems deal with applications and not with research.

These assertions should be tempered by acknowledging that programs have been written which condense numerous observations of decisions into rules of thumb for use in expert systems. Even in these cases, however, the observed decisions must originally have come from outside the expert system.

Some of the features of expert systems are described in Alty and Coombs' (1984) definition:

> the inference engine must be separate from the knowledge base; knowledge representation must be rule based; and the system can explain its answers (cited by Hearn 1987).

Optional features are the handling of uncertainty and conflicting or inconsistent information, Rules are of the if-then variety, as illustrated by Colomb (1987) and Norton (1987). Rules act on facts to produce new facts. The input facts may be part of the system's existing database of knowledge or may be obtained from the user, or in some cases the system may obtain facts from more traditional computer models (*e.g.* McKinion and Lemmon 1985, Hearn 1987).

Basden (1984) listed the following advantages of expert systems over human experts;

(1) Reliability. Humans forget things;

(2) Consistency in weightings and in dealing with risk;

(3) Accessibility. Computers do not take holidays;

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(4) Speed;

(5) Easier duplication of expertise. Copying a program is easier than training staff.

However, other sorts of computer programs share similar advantages over human experts. More relevant to this discussion is Basden's list of expert systems advantages over more traditional computer systems for decision support:

(1) Flexibility of expression. Rigorous formal expertise as well as rules of thumb can be incorporated;

(2) Human-like processing. The inclusion of rules rather than mathematically derived solutions facilitates user interrogation of the system for its reasoning;

(3) Ease of expression. Even non-programmers can understand the program code;

(4) Uncertainty and contradictory evidence can be handled.

These advantages should not, however, be overstated. Rules of thumb can be employed in the application of most, if not all, mathematical techniques. The inclusion of mathematical models in the decision support system, as is often required for agricultural problems, makes user interrogation difficult or limited to parts of the system. In any case, the importance of an explanatory facility tends to be over-emphasised by some expert system advocates. Forsyth (1984a, p. 14) asserted that:

> a reasoning method that cannot be explained to a person is unsatisfactory, even if it performs better than a human expert.

Assuming that by "a person" Forsyth meant a non-expert user, this statement seems to be unnecessarily restrictive and to preclude use of a great many useful mathematical techniques. For example, output from a mathematical programming model may be extremely useful, even if it is difficult to tell from the output what are the most important factors making a particular solution better than the alternatives.

My experience with the programming language Prolog, one of the languages used for expert system construction, is that it is not easier to read than modern procedural languages such as Pascal. Use of an expert system "shell" eases construction and understanding of the program, but similar tools are available for mathematical techniques such as simulation modelling and mathematical programming.

Agricultural economists may find the treatment of uncertainty in many expert system shells and particular expert systems to be unsatisfactory. A very small number take a Bayesian approach (*e.g.* see Naylor 1984) but, of the systems which include uncertainty, the vast majority use certainty factors (*e.g.* Shortliffe 1976) or fuzzy logic (Mamdani and Gaines 1981). These approaches have "somewhat shaky" theoretical foundations (Forsyth 1984b). Colomb (1987) illustrated the use of certainty factors with the example: "The condition is *fusarium* wilt with 85% confidence". The "85% confidence" qualifier is not a probability although in this case it might reasonably be interpreted as one. Difficulty arises when trying to interpret certainty factors for variables with more than two possible values, *e.g.* "There are ten insects per square metre with 70 per cent confidence". In this case, the certainty factor has no rigorous interpretation. It might be described as the strength of conviction or degree of gut feeling. The approach cannot handle the specification of a probability distribution which would be preferable for continuous or multi-level variables.

O'Keefe *et al.* (1986) observed that one of the strengths of many operations research techniques is their ability to conduct sensitivity analysis, but that expert systems provide little or no capability for sensitivity analysis. They suggested that a useful facility would be the ability to ask the system what sets of circumstances could lead to a particular conclusion. O'Keefe *et al.* also described a problem with the consultation (question and answer) method of decision support—*i.e.* "Users do not like simply answering a series of questions". They suggested that frequent positive reinforcement needs to be provided to keep the user interested.

3. Expert Systems and Agricultural Economics

In this section the possible role of expert systems in agricultural economics (particularly farm management) is discussed in the light of the preceding critique. The unsuitability of using expert systems for research has already been noted. The question, then, is whether they have a role in agricultural economics extension. I suspect that their role will be minor. The farm management problems of interest to agricultural economists generally involved optimisation or at least are very number intensive, whereas the expert system framework is best suited to problems of diagnosis and to non-numeric problems. Thus, from an agricultural economist's point of view, expert systems can look at the symptoms and diagnose the problem, but not identify its solution (unless it is very simple to derive or follows directly from identification of the problem). To be handled by expert systems, optimisation problems must be squashed into this diagnostic framework and, in order to provide explanation facilities, the results of numeric analyses must be condensed into rules of thumb. An area where expert systems may excel is in the development of user-friendly interfaces (*e.g* data collectors and report writers) for more traditional modelling techniques. For some problems it may be useful to employ the ability of expert systems to dynamically determine which facts are needed and which questions need not be asked. For other problems, particularly those with many numerical inputs and assumptions, other approaches such as microcomputer spreadsheets may be more suitable for presenting and collecting data, testing assumptions and summarising results.

The difficulties of handling optimisation problems in expert systems are illustrated by SIRATAC, the cotton pest management system described by Hearn (1987). The objective of SIRATAC is the achievement of a prespecified target yield, not profit or utility maximisation; *i.e.* the economic problems has been simplified to a technical problem. The pest thresholds used to trigger spray decisions are not determined by logical deduction within the expert systems part of the program, but by mathematical routines accessed by the expert system. Similarly, in other agricultural expert systems such as Counsellor (Jones and Crates 1985) and LATIS (Bishop *et al.* 1987), the main problems solved are technical, not economic.

Thus it is my judgment that, notwithstanding some predictions (*e.g.* Daniel 1984, Phelps 1984), expert systems are not likely to replace more traditional tools such as mathematical programming, dynamic programming, optimal control, decision analysis and marginal analysis for the *solution* of agricultural economics problems. However, it is possible that expert systems might be usefully employed to create user-friendly interfaces for more traditional techniques.

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The Place of Expert Systems in Agricultural Economics: a comment

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The points raised by Pannell are by and large well taken, and serve as a useful correction to the hyperbole which has surrounded the introduction of expert systems technology to practical problems. The following comments (from the point of view of a computer specialist) are intended to clarify the place that expert systems technology might take in agricultural economics.

First of all, that "the farm management problems of interest to agricultural economists generally involve optimisation or at least are very number intensive" sounds to a research manager like me as an identification of a field with its most commonly used tools. If the field were defined as for example *assistance of farm managers with economic decisions* then it would be possible to identify areas of the field not well suited to the present suite of tools, and easier to incorporate new tools as they became available. I agree that if a problem is well suited to numerical methods for its solution then it is probably not too productive to attempt to solve it by rule based methods. My understanding is that the decisions suggested by SIRATAC are ideally made on economic grounds. However, it is almost impossible to make an economic decision due to the need for global optimisation including the unknown future of the crop during a season, and to the presence of economic externalities such as insecticide resistance and environmental concerns. I would be very surprised if there were not a large number of problems with similar difficulties.

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