SYSTEMS ANALYSIS AND RESEARCH PRIORITIES IN ANIMAL PRODUCTION

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Summary

A case is argued for economic evaluation of research and development proposals and for closer attention to priorities for research in animal production. Some means whereby models of animal production systems might assist with these problems are suggested.

I. INTRODUCTION

Animal production is a biological process conducted so as to achieve economic objectives. On the farm, this process can be viewed as a system composed of interacting components, including soil, pasture, animals and the farmer. Within this system the farmer must interpret information from the climatic and economic environments and from the system’s components, make decisions, and endeavour to control the operation of the system so as to attain his objectives.

Research in animal production provides new information about the components of the system, their modes of operation and their interactions, as well as information about the design of the system. This new information, when it is known to the system’s manager, may assist him directly in his decision-making and controlling functions. Or, additional “development” research may be required before the new knowledge can be translated into usable techniques of production.

Such a view of animal production requires that research should provide information which is operationally “valuable” within the context of the whole system and the objectives which it serves. With limited resources available for research and development, the fact that a given project is likely to produce information of value is not a sufficient criterion for conducting that project; it should be determined which research activities would provide the highest return from these scarce resources. This suggests that priorities should be established between research proposals, and that the likely benefits of recent research findings and the innovations which might flow from them, should be evaluated relative to the private and social goals under which the animal production system is conducted.

II. RESEARCH PRIORITIES

Research, and the development of innovations, can be conceived as a production process in which inputs (scientific services and equipment) are used up and various kinds and quantities of new knowledge or new techniques (products)
are generated. In principle, research resources will be used efficiently when (a) no more resources are used than needed to produce a given package of information, (b) the collection of information outputs is geared to the relative values of different kinds and amounts of new knowledge, and (c) the total input of resources in research and development is such that the return on those resources approximates the return in the best alternative use (Kaldor 1966).

Research is largely a social investment and the costs of research must be weighed against its contributions to identifiable social goals. Gross National Product is an identifiable goal, although others, such as income distribution, may be important. The goals of the financing body and the institution conducting the research will also be important (Kaldor 1966; Paulsen and Kaldor 1968). As an investment, the costs and benefits of research are a function of time, and this must be specifically included in the evaluation by the use of discounting procedures. Application of these procedures to successfully completed research programmes has helped to elucidate the principles and the problems of research evaluation (Griliches 1957, 1958; Dick, Toynbee and Vignaux 1967). These studies have also shown that high returns to investment in agricultural research can be achieved.

Much work remains to be done on the challenging problem of predicting costs and benefits before the research or development is commenced. Such analyses will be subject to severe difficulties in measuring:
(a) the information which can be generated with a given set of research inputs, and the probabilities of success;
(b) the benefits accruing to individual farming units and to aggregates of these units;
(c) the rate at which new information or new techniques are adopted;
(d) the price and income effects of general adoption.

Although some progress has been made on these questions for research on relatively simple farming systems (Kaldor and Paulsen 1967), the formal evaluation of research on complicated systems involving animal production remains largely untouched. A first step in this direction should be a more formal evaluation of the consequences of research at the farm level. Rather than working with actual animal production systems, an appreciation of these consequences may be possible at lower cost by working with models of the systems. The use of models may also have advantages for the research process itself.

III. RESEARCH EVALUATION USING MODELS

When a mathematical model is constructed, the real system is translated into an analogous, but abstract, system. Computers have enabled large models of agricultural production to be built and operated, so that the whole-farm system can now be modelled. Such models should be rich in the biological and economic components of the system and their interactions, as well as allowing for the stochastic nature of the climatic and economic environments. When a valid model has been constructed it may be used to simulate the operations of the real system (Dent and Anderson 1971).

Such a model can be used to isolate those parts of the system where additional
knowledge is likely to be valuable in terms of the objectives of the system. This can be achieved by testing the sensitivity of the output to changes in various parameters of the model. The pay-offs, or the degrees to which the manager’s objectives (such as profits) can be increased so determined, offer a crude ranking of research alternatives.

A special class of models, namely, those employing optimising algorithms such as linear programming, have been used in this fashion (Duncan 1967). The approach used with this technique has been to construct a linear programming model of a “representative” farm and to determine research alternatives on the basis of limiting restraints on production. The problem of aggregating the pay-offs to the suggested lines of research across the farms of a region, as well as the other problems of measurement stated above, still remain if a more refined ranking of research alternatives is required. While linear programming has proved helpful for this type of sensitivity analysis, it can be disadvantaged by the simplifying assumptions which are needed to model the biological complexity of many systems and the stochastic nature of the environment. Also, linear programming and its allied techniques are not usually understood by biologists; thus a communication problem between the economist and the biologists is created. On the other hand, “simulation-type” models readily include non-linearities, stochastic elements, time lags and feed-back, thus enabling the investigator to see how changes in one parameter affect the other components and their interactions within the system; “simulation-type” models are not tied to a formal mathematical algorithm and are readily understood by all members of the evaluation team. Should optimization of the objective function be required, simulation experiments can offer this opportunity, or an optimizing algorithm may be incorporated within the simulation model.

Models of systems of animal production may also be used as testing-grounds for new techniques which may emanate from recent research findings. Here the problem may be one of system design in order to determine the placement of a potential innovation within the system. Information on the magnitude of various parameters required before the new technique will replace the old, may also be supplied. In addition, new techniques may require new decision rules for the best operation of the system.

An example of the way in which models of animal production systems might be used to test the likely commercial consequences of potential innovations is afforded by the concept of “protected proteins” (Ferguson, Hemsley and Reis 1967). The finding that wool growth can be increased by protecting the protein in the diet of the sheep from degradation in the rumen, has important implications for widening the choice of feeding strategies for wool production. An evaluation project, with the objective of determining the conditions under which such feeding strategies are likely to be profitable to farmers, has been commenced.

In order to achieve this objective, it is necessary to study the impact of protected-protein feeding, relative to existing feeding techniques, within the context of the whole farm and the environment under which the wool-producing system operates. To this end, models of representative farming systems in two major regions, namely the wheat-sheep region and the high-rainfall region, are being considered. Within these models the profitability of supplementary feeding
strategies involving different protected rations and different methods of making the rations available to sheep are being examined in relation to:

(i) the cost of treated rations, and the capital cost of feeding facilities:
(ii) the rate of wool production from the treated rations:
(iii) wool prices and wool quality:
(iv) farm size, flock size and labour efficiency:
(v) pasture utilization and stocking rates:
(vi) the profitability of alternative uses for the farmer's scarce resources.

Because the performance characteristics on the farm of an untried technique are uncertain, it is necessary to study the sensitivity of production and profit to changes in these variables. Such study will help to indicate the ranges of values of these variables which will need to exist for profitable adoption of protected-protein feeding. In turn, this information may guide biologists to seek clarification of the important relationships and to direct their development research towards the most profitable forms of protected-protein feeding.

The use of models rather than actual systems, or parts of them, as vehicles for applied or developmental research has further implications for research planning. Simulation experiments offer a means of determining response surfaces for inputs, and investigating these surfaces for optimal or near optimal levels of output (Wright and Dent 1969). Under present research technology this type of research is conducted in a repetitive and expensive fashion across time and space. In this process the whole productive system can seldom be considered, with the consequence that, at times, the relevance of the results to the system may be questioned. In the future such experiments may decline in importance, except in extending or confirming the results of simulation experiments (Morley 1968). Not only will simulation facilitate the measuring of the benefits of such research, but it is also likely to permit a greater understanding of the amounts of research inputs needed to generate the required knowledge. Similarly, the long term behaviour of many grazing systems is important, but expensive, knowledge. Once the fundamental biological relationships have been quantified, the necessary long term experiments may be conducted more cheaply and efficiently by simulation.

IV. FINALE

The future is likely to bring increasing emphasis on research planning and evaluation. This paper has suggested some ways by which the concepts of systems analysis and simulation can aid this process. If both these ideas are to make the contributions of which they are capable, it will be necessary to have greater communication and co-ordination between disciplines and research institutions than presently exist. Research evaluation, along with systems analysis, requires an integrated team approach. Unless we, as scientists and economists, take the lead in this direction we may have a more rigid framework forced upon us.

Just as biological researchers need to look to the allocation of their resources, so too do systems' researchers. The overhead costs of model-building is high, and to build a separate model of a given system for each task, including research
evaluation, would be wasteful. As far as is possible, generality and flexibility of use, aided by modular construction, will be worth attaining. In the operating phase, systems’ researchers must be mindful of the so-called Third Law of Simulation (Dillon 1971). Unlike other “Third Laws” this one is mutable.

V. REFERENCES