TOWARDS INTEGRATED INFORMATION SYSTEMS FOR ON-FARM DECISION SUPPORT

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Abstract: Recent advances in computer hardware, software and telecommunications technology have increased the possibilities for effective computer-based support of farm management. More and more knowledge-intensive models from research become available that could be integrated in commercial information systems. In the paper such models in livestock farming are presented and discussed in the light of integrated information systems for on-farm decision support.

Keywords: Farm management, Individual farm analysis, Dynamic programming, Computer simulation, Integrated information systems

1. INTRODUCTION

Management is becoming increasingly important in modern livestock farming. The critical aspect of good management is making the right decisions. The process of decision making is commonly described in five steps (Boehlje and Eidman, 1984):

1. define the problem or opportunity,
2. identify alternative courses of action,
3. gather information and analyse each of the alternative actions,
4. make the decision and take the action,
5. evaluate the outcome.

Current commercial information systems are not yet well suited to support the various steps of the farmer's decision-making process. They are mainly restricted to recording and some analysis of empirical data, but do not allow, for instance, for a systematic (and automatic) search for strong and weak elements in the management nor for the calculation of the optimal decisions and the impact of alternative management strategies on future farm performance.

Within the department of Farm Management of the Wageningen Agricultural University extensive research in livestock farming has been carried out to develop and apply more advanced modelling techniques that could be integrated in information systems in order to support more steps of the decision-making process. These models are able to use records of individual farms, and have the ability to interface with each other for exchange of input and output ("seamless integration"). All models are programmed in Turbo Pascal and run on a PC. The models are primarily focused on Dutch conditions, but can easily be modified to suit other price and farming conditions.

In the paper the essence of each of the modelling approaches and their type of outcome for use in on-farm decision making will briefly be described. Subsequently attention will be paid on how to proceed from the available research prototypes towards successful implementation in the field as part of an integrated information system.

2. ADVANCED MODELS UNDER CONSIDERATION

2.1 *Individual farm analysis*

First an expert system type of approach was developed, focused on individual farm analysis and aimed at determining the strong and weak elements in the farmer's management (Huirne, 1990). The system, named CHESS (Computerized Herd Evaluation System for Sows), identifies and ranks the relevant deviations between the farm's performance and standards, and hence can support the first step of the decision-making process (ie, "define the problem or opportunity"). Three types of analysis are included in the system: (1) comparative analysis, in which the farm's performance is compared with that of other farms, (2) trend analysis, to evaluate the development of the farm over time, and (3) comparative trend analysis, to evaluate differences between the development of the farm and that of a group of similar farms.

Because of the many uncertainties in agricultural production, deviations between performance and standards always exist. Key-question then is what deviations are to be considered relevant for further action. False signals should be avoided and real problems not overlooked. For that CHESS includes and combines two criteria: the economic importance and the statistical impact of traced deviations.

The economic importance of one unit of deviation differs among farm and price conditions (Jalvingh, 1993). One common economic weight, eg, one day longer interval between two farrowings costs X guilders, therefore, is not realistic (although often applied in available commercial systems and/or simple economic models). CHESS has the opportunity to determine farm-specific economic weights for all variables included, using computer simulation tools (see section 2.3).

As a measure of statistical importance, the traced deviation of a variable j (TD_j) is related to its standard deviation (SD_j). The statistical importance (SI_j) of a deviation increases if the ratio between traced deviation and standard deviation increases, ie, $SI_j = TD_j / SD_j$. Standard deviations must be obtained for each of the three types of analysis. They are easily calculated from farm-specific databases, which are increasingly available on farms.

In determining the relevance of a deviation, both the economic (EI_j) and statistical importance (SI_j) are taken into account. The relevance of a deviation (RD_j) is calculated by multiplying the economic importance by the absolute value of the statistical importance of a deviation in performance variable j. In formula: $RD_j = EI_j * |SI_j|$. The absolute value in the formula is used only to avoid changes in sign in the economic importance of a deviation. Finally, all deviations are ranked according to their RD. In this way, a weak element in the management can rank high according to its economic impact (ie, a lot of money to gain from improvement), its statistical impact (ie, improvement should be possible, as others show better results on this issue), or both.

The system has been made operational for sow herds. It has the ability to interface with both external simulation and optimization models for data exchange, and with management information systems for automated data input. For dairy farms no such system exits yet, at least not along the lines described in this section.

2.2 *Optimal decision making on individual animals within the herd*

Farmers must frequently take decisions on individual animals within the herd. These include decisions on type and level of feeding, insemination, and treatment in case of fertility and health problems (Dijkhuizen, 1992). In each case usually several options are available, and the question then is what option is the best. Referring back to the five steps in the decision-making process within the farmer's management (see Introduction section), a model to help answering this question would especially support step 2 (ie, "Identify alternative courses of action").

Decisions at the animal level all include replacement as one of the alternatives. The income potential of the replacement animal cannot be realized as long as the available animal is kept in the herd, and, therefore, can be interpreted as the opportunity costs of postponed replacement (Dijkhuizen, 1992). So, the net revenue of not only the animals present in the herd but rather the net revenues of the present and all subsequent replacement animals, have to be maximized.

Dynamic programming is considered the most appropriate technique for determining the optimal decisions at the animal level (Kristensen, 1993). It allows non-linear relationships, genetic improvement, seasonal variation and uncertainty in future performance of both the present and all subsequent replacement animals to be included.

In the Netherlands, extensive research has been carried out to apply the dynamic programming technique to sows (Huirne, 1990) and cows (Houben, 1995). With the available models decisions can now be optimized for animals that differ in age, productive capacity, reproductive performance and health status, using individual animal and farm performance levels and prices. Major outcome of the models is an economic index - called Retention Pay-Off (RPO) - that enables ranking of the animals within the herd on their future profitability: the higher the RPO, the more valuable the animal. A value below zero means that replacement is the most profitable choice. The value also indicates the maximum amount of money that could be spent to treat sick animals that otherwise have to be replaced.

Results show that selection on insufficient productive capacity, apart from any disease, should be significantly stronger in cows than in sows. The key-factor here is the repeatability of performance across parities, which is much higher for milk production than for litter size. Reproductive performance, on the other hand, is economically much more important in sows than in cows. Costs of a one-day delay in conception, for instance, reduces annual sow income on a typical farm by about 1% against 0.1 to 0.3% in cows (Jalvingh, 1993). So, culling on reproductive failure should be significantly stronger in sows than in cows. This means that fewer number of inseminations are allowed before the RPO-index falls below zero and replacement becomes the more profitable option.

2.3 *Farm-specific simulation of herd management strategies*

In the Netherlands a project called TACT-Systems (TActics and ConTrol) has been carried out to extend available systems in dairy cattle and swine with computer simulation, suitable to run on a PC (Jalvingh, 1993). Simulation models offer the possibility to provide farmers (and advisers) beforehand with insight into the technical and economic consequences of changes in performances, prices and management strategies. Moreover they can help to provide additional information on their potential impact on the results through sensitivity analysis ("what..if" calculations). In this way, simulation models especially support steps 2 and 3 of the decision-making process (ie, "identify alternative courses of action" and "analyse each of the alternative actions", respectivily), but the predicted outcome of the management strategy that the farmer is going to apply can also serve as a farm-specific standard against which the realized performances can be evaluated (step 5).

Key issue in the TACT-modelling approach is the simulation of the flow of animals and their performances through time (see Figure 1). The simulation is able to take into account farm- and animal-specific biological probabilities (eg, oestrus detection and pregnancy rate and production capacity) and management strategies (eg, feeding, insemination and replacement policies). Central in the approach are the concepts of states and state transitions. A state is defined as a condition in which an animal can be, such as "pregnant" or "culled". A transition means that an animal goes from one state to another, eg, from open to pregnant. The distribution of animals over states at a certain moment can be

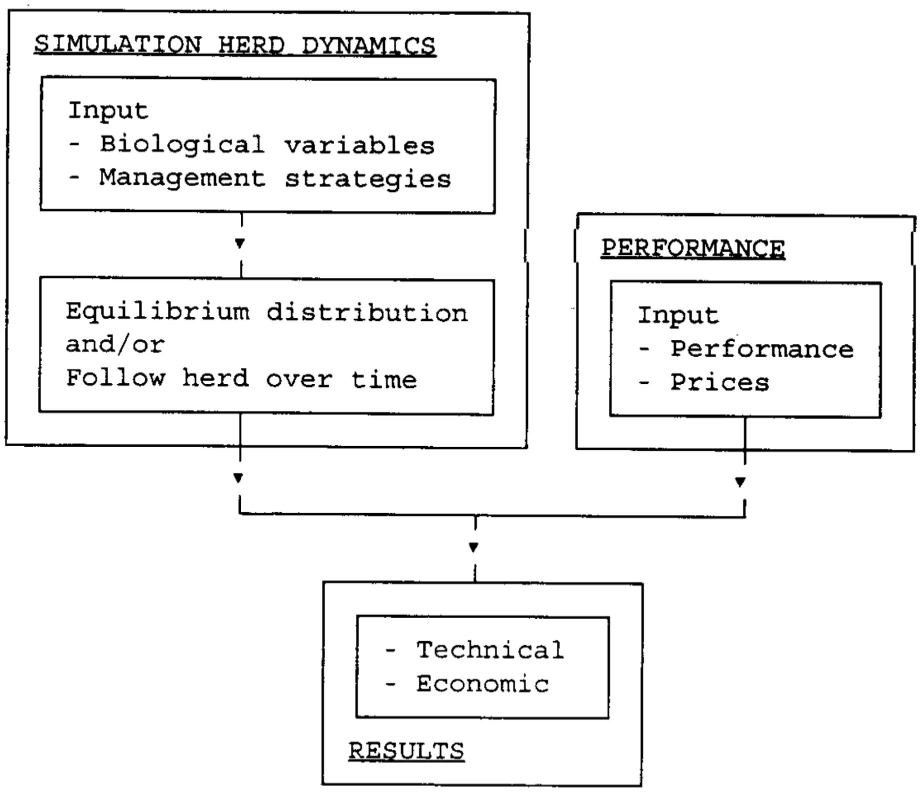

Figure 1. Overview of the TACT-modelling approach.

derived from the distribution at the moment before and the transitions possible for each state. Uncertainty in future performance and prices of the animals can be included and is represented in four groups of transition probabilities: production, reproduction, disposal, and replacement. The possibility to include such uncertainties in the model is a major step forwards compared to the so-called deterministic models such as partial budgeting and linear programming. The current approach allows for individual animals that vary in performance among each other as well as over time, and hence these animals can be fed and treated differently, whereas deterministic models usually include average animals only and calculate with future performances and prices that are assumed to be known (Jalvingh, 1993).

Technical and economic results of the herd are calculated by combining the number of animals per state with information from the performance model on milk or piglet production, feed intake, slaughter value and prices (Figure 1). Insemination and replacement of individual animals can be determined by the outcome of a third model, ie, the dynamic programming model in either sows (Huirne, 1990) or cows (Houben, 1995). The use of the results of the dynamic programming model in the herd dynamics model is optional, however, and to be replaced by more simple rules such as user-defined rules of thumb (eg, animals older than 8 parities are culled and replaced any way). Technical and economic results can be generated for a herd in its steady state (equilibrium distribution) or for different consecutive years of the herd. The latter offers insight into the way the herd approaches a new steady state.

3. PRACTICAL APPLICATION OF THE MODELS

Suggestions for the development of the models described in this paper were generated from the so-called information models (Verheijden et al., 1985; Brand et al., 1986) and from discussions with farmers and agricultural and veterinary advisers. So far the development of the models has mainly be focused on the application and illustration of the techniques used. The knowledge thus acquired has been structured and included in the prototype. The results of the research have been published - in scientific as well as in popular journals - and made operational. Now the time seems ripe for the next step: making the prototypes available for on-farm use while involving the potential users (ie, farmers and advisers). This seems to be late in the process of development, but has the great advantage of having prototypes available to look at and evaluate. That helps structure the ideas on both potential applications and necessary adjustments of the models.

From the literature (Alter, 1980) as well as from the discussions with the potential users different usage patterns of the models can be distinguished. The first usage pattern is called central use or "in service". This has the advantage to minimise the barriers to participate and/or make use of the system. Farmers and advisers can experience the possibilities of the use with less effort and investment and can switch to one's own PC after a certain period (if desired). For the TACT-Dairy simulation models the Dutch Cattle Syndicate (NRS) is currently setting up a structure to provide this service. The second usage is as stand-alone model on the PC. In this way the current models are all used for training purposes. That offers the possibility for potential users to gain more insight into the type of information and decision support these models can provide. Moreover, single advisers are interested in this type of use on their own PC to generate rules of thumb for their advice to individual farmers. Finally, one of the models describe above (ie, the stochastic dynamic programming model in swine) has been integrated in the commercial CBK swine information system (De Vries et al., 1994), indicated as the third usage pattern. The model is automatically fed with data of the specific farm under consideration and provide the output within the available information system. A specific interface has been developed for physical transfer of data and outcome. Much attention was paid to check farm data on inconsistency and other disturbing factors. Experiences so far from users are positive.

4. FINAL REMARKS

Farm information systems in the Netherlands (and elsewhere) are currently ex panding in scope to become what is called decision support systems. Such systems are defined as interactive computer-based systems that help decision makers utilize data and models (Sprague and Carlson, 1982). The combination of data and models makes it possible to support mòre steps of the farmers' decision-making process. First experiences with making prototypes from research available for use in the field are positive. It is an intensive process to go through, with various groups being in volved (ie, the developers of the models, the potential users - farmers and advisers - and the commercial software agencies). This interactions is considered fundamental to define and meet the standards for use in practice. Moreover, training of the users turned out to be essential for a successful implementation. Hence, not only the users but also the developers of the model should play a central role in the process towards practical application. The Wageningen Agricultural University, however, does not want to be involved routinely in such activities, as teaching and research are considered to be the core activities. Experiences so far showed that more practical oriented research institutes nor extension type of organizations were able or willing to fulfil this role. Hence, the developers of the models from within the Department of Farm Management of the Wageningen Agricultural University themselves recently started a commercially-based service, aimed at bridging the gap between modelling research and use of the models in the field. Key activities include to carry out the user-defined modifications of the models for either stand-alone use or for integration in commercial information systems, and to provide pratical training courses in the use of the models. Maintenance of the applications could also be organized in this way.

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