The need and design of computerized farm management tools

Lessons learned from a Swedish case

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Abstract
In the 1980s the author was responsible for the development and marketing of on-farm computer systems in Sweden. Despite the efforts to use the best available knowledge and technology, the adoption rate was lower than expected. The aim of this review is to explain the slow adoption rate and suggest how computerized management tools should be designed to meet the needs of farmers. Many studies have been made trying to understand this problem, among others by the author. These studies are referred to in this review together with mainly reference to psychological literature. One main explanation of the slow adoption of on-farm computer systems is that computerized management tools produce analytic information, while farmers are using to a great extent intuitive thinking and intuition for decision making. According to one study, even the farmers using analytic thinking, in addition to their intuition, prefer “intuitive” information. Analytic methods have to be used in computerized management tools, of course, but the adoption experience suggests that the output information from on-farm computer systems should be further processed to fit intuitive thinking.

Introduction
Many farm management tools aimed for farmers as well as advisors are not leaving the desk where they are developed. We know what the farmers should do but not so much about what the farmers actually are doing. In 1977 the Swedish University of Agricultural Sciences started the project “Farmers’ need and use of management tools” and in 1978 the project “Development of computer-based tools for education, extension service and research in farm management”. In 1979 the author of this chapter visited the U.S. and Canada in order to gather information for these two projects. The visit resulted in a structuring of information about the need for, and design of, computerized farm management tools (Öhlmér and Nott, 1979). Farmers’ management tasks were presented as an hypothesized outline, and citations of several published studies ranging from case studies to large sample surveys were made to provide evidence about which management tasks the respondent farmers thought were the most troublesome. Four ways of using computer systems in providing farm management help were described and compared:

1. Farmer owned programmable hand calculators.
2. Farmer owned microcomputers.
3. Organization provided interactive farm computing
4. Mail-in system with a maxicomputer

Each way was described in terms of (a) the hardware for communication, storing data and doing computations, (b) the software (both the type of algorithm and computer language), (c) the delivery system that links the model together from hardware through end use, and (d) the use actually made of the computer output by the farmer (i.e., the using system). The final part of the study was a case study of computerized farm management tools available to Michigan farmers at that time and how they compared to the outline of management tasks.

An on-farm computer system for Swedish conditions was suggested (Öhlmér, 1981), and the Swedish farmer union and cooperative organizations let their computer center develop on-farm computer systems for accounting, production planning and performance control. The production packages included items for milk production, piglet production, fattening pig production, egg production and crop production. The hardware was at the start 1981 microcomputers and CPM operative system, and later PC and DOS. The farmers' accounting service organization was engaged as field organization. A course material was developed (Pavasson and Öhlmér, 1983) and workshops were organized all over Sweden. The on-farm computer system was aimed to support farmers' repetitive tasks in financial, production and marketing management with daily or weekly use of the system. One to two thousand farmers used the system, which was much below the expectations. One lesson learned was that farmers with high education used the systems and found them very valuable, but other farmers didn't like the systems at all. Some complaints regarded time-consuming data entry and high price.

Nowadays, the "computer literacy" has improved, which has reduced the *education constraint* somewhat, but it has not affected the ability to understand the information content. The *data entry problem* has successively been reduced through automated data collecting (Nilsson, 1987). The initially high *hardware and software price* has been reduced considerably. However, the problem of slow adoption still persists, and it is the same in other countries as discussed on international conferences as well as in other chapters of this book. Farmers with high education are using IT but other farmers are lagging behind (Batte, Jones and Schnitkey 1990, Brink and Josephson 1986, Putler and Zilberman 1988, Öhlmér 1989). The aim of this chapter is to explain how human information processing may influence the adoption rate and explore how computerized management tools could be designed to meet the needs of farmers. We will look in more detail on how farmers actually are processing and using information, and how computerized management tools might fit in.

Management tools produce analytic information and farmers use intuition

Hammond (1996, p. 60) states, "the ordinary meaning of intuition signifies the opposite – a cognitive process that somehow produces an answer, solution or idea without the conscious, logically defensible step-by-step process". In contrast to analysis, intuition cannot be defended or justified by a "step-by-step" process. Non-intuitive processes are deliberate and can be specified after the fact and made transparent. Intuition cannot. Hogarth (2001, p. 14) proposes, "the essence of intuition or intuitive responses is that they are reached with little apparent effort, and typically without conscious awareness. They involve little or no conscious deliberation." The definition might seem to cover all cognitive processes of which we are not aware. This is not meant to be the case. We will come back later to a more precise definition.

Öhlmér et al. (1997) and Öhlmér (1998) studied farmers' detection of problems and finding ideas of resolutions, respectively, in relation to the decision by the Swedish Parliament in 1990 to apply for EC membership. This decision meant that Swedish farmers would face price decreases, higher price variations, higher price uncertainty and marketing difficulties for their traditional products. In 1990, experts expected prices to decrease 20-30 %, and a governmental program to support farmers' adaptation to the new conditions was decided. Adapting to this change was a unique problem not faced before and it affected the entire farm situation. Data collected with a retrospective questionnaire answered by 193 farmers (equal to 62 % approved responses) was analyzed with path analysis and the Maximum Likelihood estimator using structural equation modeling. The questions asked regarded time spent on external information scanning, information sources, way of processing information, perceived changes in prices, support levels and farm income, perceived magnitude of the problem, resolution options identified etc., as well as characteristics of the farmer, the farm and the environment (external to the farm) influencing the farmer behavior. They found that the analytic problem detection process was different from the intuitive process. In the analytic process, farmers had a logic, stepwise procedure, in which they: (1) paid attention to changes in relevant conditions, (2) estimated the consequences of the perceived changes, and (3) evaluated if the consequences would be a problem.

In the intuitive process, farmers did not use these steps, but paid attention to information about the magnitude of the problem directly from the external information source. Information in mass media, advisory activities, management service and management tools were quantitative, and designed for a logic stepwise procedure of problem detection. About 25 % of the respondents used the analytic process. Farmers using only the intuitive process wanted information focusing on the evaluation of the problem and describing the changes in terms of directions from current conditions. In the analytic process, farmers used mainly mass media and group activities as information sources, and in the intuitive process mainly group activities and individual advisory service. Mass media had a lot of information about the changes at an early stage. (The contribution of ICT to each group's use of each source of external information was not studied.)

The environment external to the farm was important for the intuitive problem detection process. The environment was measured as the distance to the closest town. The consultants and the advisory service have their offices in towns. Farmers' suppliers and organizations have also their offices in towns. Workshops, seminars, demonstrations and similar activities are more often arranged in the towns than in areas more far from towns. It was easier to get individual advice in the towns or close to towns, and it was easier to establish a rich personal network closer to the towns. The analytic process seemed to be more independent of the distance. There were no significant differences in perceived magnitude of the problem or time of problem detection between the two types of processes.

Regarding problem definition, farmers using more processed information in the form of, e.g., advisory service, found options having greater estimated consequences on incomes and investments. However, more information did not seem to improve the creativity in the option generation. The level of creativity was dependent of problem magnitude, ability, degree of quantification and motivation. These factors were related to the ability to perceive and attend. Thus, these factors were more important for option generation than the amount of information.

Farmers' ability had a great influence on the problem detection as well as problem definition in both the analytic and intuitive processes. Avoidance had also a great influence on both the analytic and intuitive problem detection. A farmer, who had another problem such as a divorce or an economic problem, did not like to read about, listen to or discuss more problems. This could be an effect of lack of time but more probably an effect of not being able to stand more negative information, which could be compared to Janis and Mann's (1977) concept of "defensive avoidance".

Lunneryd (2003) studied farmers' information search in strategic decision making, especially in the analysis and choice phase. Whether converting from conventional to organic milk production was used as a case to learn more about farmers' decision making and search of information. A questionnaire was sent in 2000 to 868 organic and conventional milk producing farmers with 56 % response rate. The questions regarded farmers' behavior in information collecting, information processing, estimating consequences, evaluating and choosing as well as characteristics of the farmer, the farm and the environment (external to the farm) influencing the farmer behavior. A dropout analysis showed that there were no significant differences between respondents and nonrespondents. Data was analyzed with path analysis and the Maximum Likelihood estimator using structural equation modeling. The results showed that the information about converting to organic farming was not adapted to the farmers' special needs. The information was not always adequate to make the decision. Some of it could not be considered as information because it did not properly relate to the farmer's knowledge. Most farmers used only an intuitive process in the decision making, but the information was developed for the analytic process.

Farmers converted their milk production to organic production by either ideological or profitability reasons, or both. The profitability reason had become more common the last years, and in 1997 they were more important than ideological reasons among converters. Farmers needed information about current and future profitability in organic production, apart from its effect on the environment. Farmers using the analytic process were interested in direct economic factors such as future demand, rules, and support levels. Farmers using only the intuitive process were more interested in production factors that have an indirect effect on profitability such as production technology and delivery rules. Important sources were professional journals, advisors (individual service as well as courses), and neighbors. Mass media did not contain so much information about organic production, and consequently its ranking was low. (However, studies of other problems discussed in mass media show that also mass media can be an important source.) Based on Lunneryd's study, we can conclude that the analytic process needed detailed information and figures about the various sub-processes, incomes and costs, and that the intuitive process needed more qualitative information related to their current production or a model farm, such as change in production levels, input levels and profitability if they would convert.

Öhlmér and Lönnstedt (2004) investigated Swedish milk farmers' use of accounting information in an experiment, where they sent 194 milk farmers a description of a case milk farm including accounting reports, and asked the respondents to identify eventual problems and options for resolution. Half of the respondents got the regular year end accounting reports, and the other half also verbal explanations formulated by experienced accounting consultants in the same way as they usually explain accounting data for their farmer clients. These verbal explanations were called "intuitive" information. The response rate was 42 %. A dropout analysis showed that there were no significant differences between respondents and nonrespondents. Data was analyzed with path analysis and the Maximum Likelihood estimator using structural equation modeling. One third of the farmers used only the "intuitive" information when detecting the problems and two thirds also analysis. Farmers using only intuition appreciated the "intuitive" information more than the regular accounting reports, as expected. However, farmers using analytic methods also appreciated the "intuitive" information the most. So, all respondents used the "intuitive" information and the intuitive process, and two thirds also the regular accounting report together with the analytic process. The latter group used all available information, which is logical. This information can be very useful for future management package design – such a program should produce improved human *"intuitive" pointers* in addition to the analysis.

The described studies by Öhlmér et al. (1997) and Öhlmér (1998) regarded adaptation to changed institutional conditions, and the described study by Lunneryd (2003) regarded the decision whether converting from conventional to organic milk production. These problems are unique, meaning that the farmers have not encountered the same problem previously. The unique decisions often concern major considerations with substantial economic consequences. They are one-time decisions, which do not return. The problem situation is often new for the decision maker, which makes it difficult to find action alternatives, learn, and evaluate the consequences. The long planning horizon also makes information more uncertain. The whole situation of the manager is affected, which makes it difficult to weigh the consequences and value dimensions together to one measure. The level of probable deviation from the expected value is often very high and so is the outcome level. Since the decision is only made once, the outcome of the single decision becomes very important. The manager must be sure that the business can manage a not too unlikely negative deviation from expected value. However, farmers have probably solved unique problems previously and have acquired some experiences of a procedure to handle such problems. (Designing a computer package for assisting farmers in this procedure is an issue not yet resolved.)

The study by Öhlmér and Lönnstedt (2004) about problem detection regarded both unique problems and problems that the farmer had met before, i.e. repetitive problems, such as problems regarding feeding and animal health. Repetitive decisions are decisions that are made several times, and consequently, have been faced before by the decision maker, probably concerning a smaller matter. For repetitive decisions the problem situation, action alternatives and consequences are relatively well known, since the decisions are made recurrently. Only a few of the goals are affected and the consequences could usually be weighted to one measure, such as profit. The level of probable deviation from the expected value is mostly acceptable. Since the same decision is made recurrently during a longer period of time, it's more interesting to get as good result as possible for a series of decisions in a longer period, than in a single decision. Thus, for repetitive decisions, such as least cost feed rationing, the normative micro economic theory is applicable

Farmers need of management tools regarding repetitive problems are expected to be large because these problems are rather frequent. The on-farm computer systems introduced in Sweden 1981, as discussed previously, as well as similar systems in other countries, contained management tools for repetitive problems and the analytical methods used were applicable to the problems. However, the adoption rate was rather low. One important explanation seems to be that *farmers use intuition to a great extent, while computers produce quantitative information aimed for analytic thinking*. This explains also why the farmers, which had adopted computerized management tools, found those tools very useful, were the most educated farmers and trained in analytic methods (and thinking). However, we still do not know how to design computerized farm management tools to be useful for intuitive thinking. We need to go deeper into farmers' information processing.

Farmers' information processing

Öhlmér et al. (1998) have suggested a conceptual model of the analytic problem solving or decision making process (table 1). They distinguish between four functions:

- Problem detection, resulting in detection of a problem or not;
- Problem definition, resulting in choice of options for further development;
- Analysis and choice, resulting in choice of one or more options;
- Implementation, resulting in output consequences and responsibility bearing.

Each function includes four sub-processes:

- Searching information and paying attention to relevant information;
- Planning and forecasting consequences of the new information;
- Evaluating consequences and choosing alternative(s);
- Bearing responsibility of the choice.

Table 1. Conceptual model of the decision making process (Öhlmér et al., 1998)

	Subprocess			
Function	**Searching & paying attention**	**Planning & forecasting**	**Evaluating & choosing**	**Bearing responsibility**
Problem detection	Information scanning; paying attention	Forecasting consequences	Consequence evaluation; problem?	Checking the choice
Problem definition	Information search; finding options	Forecasting consequences	Consequence evaluation; choice of option to study	Checking the choice
Analysis & choice of option	Information search	Planning & forecasting consequences	Consequence evaluation; choice of option	Checking the choice
Implementation or action	Information search; Clues to outcomes	Forecasting outcomes and consequences	Consequence evaluation; choice of corrective action(s)	Bearing responsibility for final outcome; feed forward information

Farmers are not expected to follow a common set of steps in a simple, sequential process. Each function and sub-process gives the farmer a deeper understanding that normally cause the farmer to revise the outcome of earlier functions and sub-processes.

Search for and paying attention to (external) information is included as a subprocess in all the functions. The information is combined with experiences and other knowledge stored in the long term memory and used for estimating consequences and evaluating them. In problem detection, consequences of differences between expected and observed information are forecasted. In the other functions, consequences refer to broad consequences of option ideas, more detailed consequences of an option, and consequences of differences in planned and forecasted outcomes, respectively. The managers need different information in the different functions of the decision making process.

The model concepts have been tested to be significant in the previous cited studies made by Öhlmér et al. (1997), Öhlmér (1998) and Lunneryd (2003). The model concepts and relationships were significant for farmers using analytic methods. Farmers using only intuition had significant relationships directly between perceived information and conclusions about (i) detected problems, (ii) identified options, and (iii) options chosen to be implemented. It means that the farmers processed the information to conclusions but they were unaware of the how they processed it. Hogarth (2001) presents a model of the human thinking process that includes tacit and deliberate systems, and Klein et al. (2005) present a model of how the intuitive system might work. In figure 1 these two models are combined.

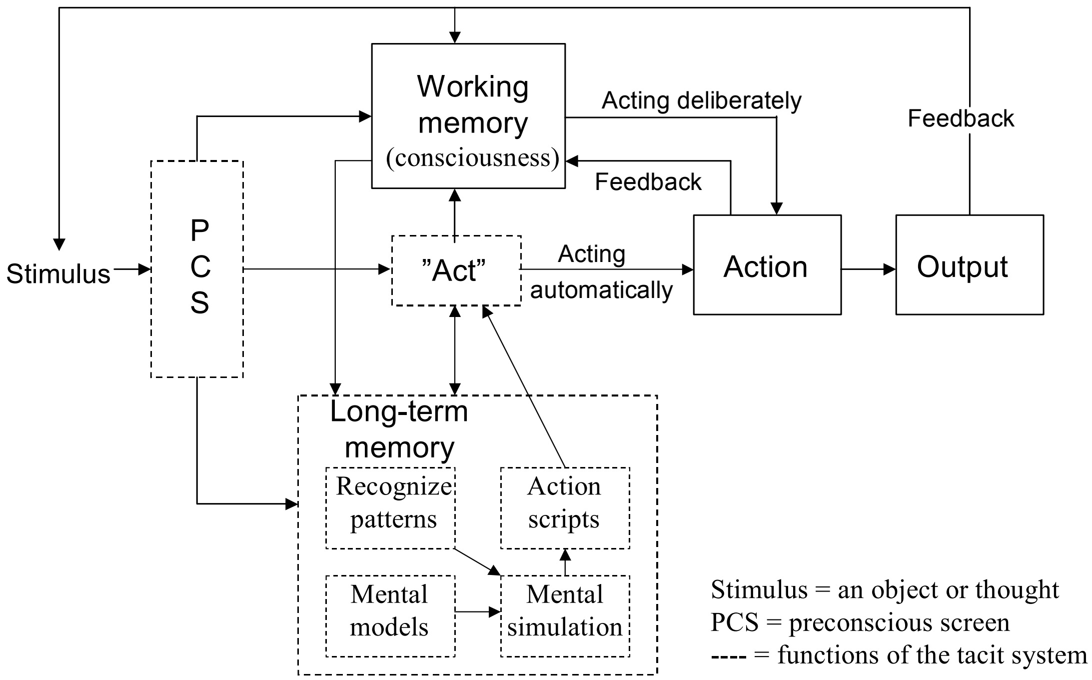

Figure 1. The tacit and deliberate systems of human information processing (after Hogarth, 2001, and Klein et al., 2005)

We assume that the tacit and the deliberate systems control the processes by which we learn and take action. There are actually more than two systems involved, but this twofold division is sufficiently rich to explore the topic of intuition. Hogarth (2001, p. 21), "the term *tacit system* is meant to encompass all processes that occur tacitly or automatically, that is, largely without conscious attention." It therefore includes intuition. It also includes what is learned through experience with the expenditure of little or no conscious attention. "The term *deliberate system* is meant to encompass all processes that require effort, that is, attention and deliberation" (Hogarth, 2001, p. 21). While it includes analysis or logic, it does not exclude processes that do not conform to any known rules of analysis or logic. All processes included in the deliberate system involve the explicit manipulation of cognition. Learning taking place within the deliberate system demands explicit effort and attention.

According to Hogarth, a mental process is started by a *stimulus*. The stimulus can be external to the person, such as something that is seen, heard or felt. It can also be internal, such as that a thought may trigger other thoughts. The stimulus is initially processed by a *preconscious screen*, which is an automatic mechanism that decides whether the stimulus will or will not enter consciousness. If not, it can be stored without awareness in the long-term memory for possible future use, and an action can eventually be taken automatically. If an action is taken automatically, the person is aware of the action only after it has been taken. Typically, we like to think that our actions are the result of our own goals and wishes. The system described has the implication that such an action may determine the person's intentions, so an action may actually precede the intentions. The ability to record stimulus without conscious awareness is very valuable because the deliberate system is a limited resource and must be used sparingly, while the long-term memory is almost unlimited. However, the system does have costs. One is that the tacit knowledge is a function of the particular environment that a person faces and, if the learning structure is wicked, such learning may not be functional. Another is that much tacit exposure to certain experience is likely to induce confidence, but we don't know explicitly how we acquired this knowledge so it is difficult to assess whether our confidence is justified. Conscious attention is a limited resource, and it is allocated to tasks that are judged to be important at given moments in time. The deliberate system is invoked either when the tacit system cannot solve the problem or task at hand, or when the person is making some conscious decision. At any given time, however, both the tacit and deliberate systems will be operating simultaneously. When working on the same task, the tacit system seeks to identify aspects of the problem to which it can relate, such as patterns, and the deliberate system tries to work through the problem in a more effortful, step-by-step procedure. If the task is familiar, the tacit system quickly finds an answer, and the deliberate system is then used only to check it or not used at all.

The preconscious screen generates information that may include cues. These cues let the tacit system recognize patterns that activate action scripts, which the system can access by mental simulation using mental models (Klein et al., 2005). The tacit system relies heavily on experience within the relevant subject area. If the problem is repetitive, such as controlling weeds and spraying herbicides, and feedback on the action output is available and accurate, experience will be built up that allow the tacit system to produce accurate "acts", such as judgements about (i) if there is a problem, (ii) what options that may solve the problem, (iii) how the options could be implemented and which options to choose, and (iv) what corrections that are needed during implementation. The deliberate system may only need to check if the "act" in question is accurate. Thus, analytic information may not be needed, which could explain the low adoption rate of management tools for solving repetitive problems.

Also when solving unique problems some moments may come back, such as some patterns of problem symptoms, some patterns of environmental cues, some mental models that allow to forecast what will happen etc., which would allow a manager to build up experience provided that accurate feedback is available. For both repetitive and unique problem solving correct feedback is needed to improve intuition. Feedback improves pattern conceptions, relationships between cues and patterns, the mental models, and the action scripts.

The Dutch EPIPRE wheat disease control program (Blokker 1984) could be an illustration of a consequence of the human information processing. It was found that every year around 3000 farmers were using the program while it was expected that over time the number would increase. What happened was that the experienced farmers, once they "learned" the program's inherent principles, didn't need the analytic information and would drop out after a year or two while "new" farmers joined. The result was that the number of users remained constant.

How can computerized management tools assist?

Referring to the tacit and deliberate systems illustrated in figure 1, computerized management tools may:

- Produce stimulus for preconscious screening;
- Assist the deliberate analysis including checking and verifying intuition;
- Provide feedback.

Computerized management tools produce information that could be stimulus for the preconscious screening. The information could be of importance for any of the four functions listed in table 1 and relevant for the subprocess searching and paying attention, but in case of the tacit system the information will go directly to the long-term memory without any attention. It forms a basis for the subprocess planning and forecasting deliberately or intuitively.

Computerized management tools may assist the deliberate analysis in the subprocess planning and forecasting. Thus the tool may (1a) diagnose problems and produce information about symptoms or indicators, (1b) forecast consequences of problems, (2) suggest resolution options and forecast consequences, (3) plan options and forecast consequences, (4) plan implementation including steps, milestones, feedback procedures, and eventual corrective actions.

As a part of item 2 in the list above, computerized tools may also assist the deliberate analysis in the subprocess of evaluating and choosing if accurate values and an accurate object function can be included in the tool. If so, the tool can produce information suggesting conclusions regarding the function in respect (in the concepts of table 1).

As another part of item 2, computerized tools may assist the deliberate system by checking intuition in the same way as the two previous paragraphs suggest.

Computerized tools may provide feedback (item 3), which already is an important task of many tools. However, currently feedback consists of general information like a financial report or a production efficiency report. The feedback should regard the specific action output to be efficient, and it should be provided as soon as possible after the action was taken.

The listed three items: (1) Producing stimulus for preconscious screening, (2) Assisting the deliberate analysis including checking and verifying intuition and (3) Providing feedback, are referring to different parts of the tacit and deliberate systems according to figure 1, but they are not comparable because computerized tools produce information, so items 2 and 3 had to be information fed into the tacit and deliberate systems as stimulus. The subprocess of each function in table 1 could be one or several loops in the tacit or deliberate system. However, the information should be in a form that works as cues to recognizable patterns, i.e. that connects to the farmer's experiences and mental models. The information should relate to the farmer's long-term memory, i.e. to current situation, previous experiences or learned concepts. The information should not be general but be about, e.g. what will happen to the farm and the farmer. Information about problems and options expressed as deviations from current situation is easier to conceive than general information. If such information could not be provided, the information could be related to farmer experiences by providing information about good examples, such as case descriptions about farms with similar problems and how these problems were solved, or about farmers that have implemented relevant options, i.e., early adopters. Ideally, the farmer should visit to such model farms.

Conclusions

One main explanation to the slow adoption is that computerized management tools produce analytic information, while farmers are using intuitive thinking to a great extent. According to one study, even the farmers using analytic thinking, in addition to intuitive, prefer “intuitive” information.

Computerized management tools should be designed to produce “intuitive” or tacit information in addition to the current analytic information. Thus, they should not just produce indicators of a problem but also what will happen to the farmer’s current production, cash flow and similar, if the eventual problem is not taken care of. They should not just produce an optimal plan but also how the current situation will change and the consequences for the current goal fulfilment of these changes. The information has to relate to farmer experiences. Analytic methods have to be used in computerized management tools, of course, and it could be the same methods as previously. However, the results suggest that the output information should be further processed to fit intuitive thinking.

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