approaching a technical maturity, a prerequisite for adoption. However, the systems are still not yet enough consumer oriented. This requires a professional marketing approach with a further development phase, a prerequisite for market success.
This is a continuous process which requires the cooperation of many different people and research areas. But it is a challenging and fascinating interdisciplinary process which will have a major impact on the future of farm business activities.

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Agro informatics in Sweden

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Abstracts

The article describes the use of information technology for management purposes in Swedish agriculture. General trends in the historical development are described as a background to the present situation.

The information systems in agribusiness are completely computerized. The users operate the systems locally via terminals to main frame computers, and there is one terminal for every second employee. The systems are, among other things, used to produce management information for farmers. Examples are accounting service systems and production control systems. Advisors are using these systems or systems based on personal computers in their service to farmers.

Around 2.5 % of all Swedish farmers (or 7-8 % of full-time farmers) have invested in personal computers for management purposes. The on-farm computers are mainly used for accounting and to some extent for production control and planning. The farmers' organizations have developed the main part of the software, and they give service and support together with other actors. Research institutions produce the subject matter knowledge needed to develop the software.

Aim

The aim of the article is to describe and explain the development, organization and use of information technology in the Swedish agricultural sector. The article deals mainly with information used for management.

Development and use of Agro Informatics

Agribusiness

Agribusiness is the biggest user of information technology in the agricultural sector. Turesson and Öhlmér (1988) have described the computerization of agribusiness in Sweden. A lot of data were collected already in the 1940's in milk production control systems for breeding purposes. In the beginning it was manual data processing, in 1951 a punch card system was introduced, and in 1961 the first computer, a Bull Gamma 30.

The computerization saved labour costs. Other advantages were less reporting, more accurate and complete information, new information, faster information and easier accounting.

The organization responsible for this information system was the Swedish Association for Livestock Breeding and Production owned by the farmers, i.e., a farmer cooperative. The processing and storing capacity became too small already after one year. The capacity was doubled, and other farmer owned organizations were invited to use the resulting over-capacity. Driftsbyrån, the farmers' accounting service organization, accepted. Almost every year since then the computer has been enlarged or replaced by a bigger one, and most of the farmer owned organizations are using the facilities. The computer operations and software development have been organized in a separate company, the Agricultural EDP Centre, owned by the farmer cooperatives. Today it is one of the biggest computer centres in Europe.

The hardware was IBM and IBM compatible main frame computers. In the beginning it was batch operated. At the end of the 1970's terminals and locally operated remote batch or interactive processing began to be used. In 1990 around 16 000 terminals were connected to the Agricultural EDP Centre. Personal Computers (PC's) were introduced in the 1980's. They were used for local processing and as terminals to systems in the main frame computer.

The development has been similar in organizations that are not associated to the Agricultural EDP Centre, but their computers do not have the same high processing and storing capacity. The main frame systems are locally operated from terminals. Smaller organizations have no main frame systems and they did not computerize their information systems until the cheap PC technology was available.

The first software items were the systems for milk production control and accounting. Driftsbyrån is giving accounting service to 55 % of the Swedish farmers. There are other companies giving accounting services too. The milk production control system was used for 75 % of all dairy cows in Sweden. The sow production control system was used for 22 % of all sows. Performance control systems including calculations of the economic outcome were used by 15-20 % of the Swedish farmers (Statistiska Centralbyrån, 1990). The organizations also used systems for their administrative routines. In many organizations the administrative systems were their main use of the information technology.

Advisory service

The economic advisors used the computerized accounting system mentioned above and analysis of accounting data in their advisory service. The production advisors used the production and performance control systems in various enterprises mentioned above in their advisory service. The systems were continuously improved and new features added. A feed planning module was, for example, added to the milk production control system in the early 1970's.

In 1980 the advisors began to use programmable hand calculators for calculations, where they didn't need a lot of data. It was simpler calculations for planning purposes, such as feed rations and investment calculations. The Swedish Association for Livestock Breeding and Production developed most of the software. Eight hundred advisors were using an advisory designed programmable calculator in 1986.

In the 1980's the advisors started to use PC's. The PC's are partly a replacement for programmable calculators. They are also used as terminals to main frame systems by advisors belonging to organizations that have main frame based systems. The organizations of the advisors developed most of the software and researchers developed some of it. Finally, the advisors used the PC's for calculations that they previously did manually and they developed this software by themselves in spreadsheet systems. Examples of software are investment calculation, whole farm planning, feed planning, crop production planning, estimating consequences of joining government programs, etc.

Farmers

Farmers got reports from main frame systems from the beginning of the computerization of the agribusiness. In 1981 the Agricultural EDP Centre began to provide farmers with on-farm computer systems. The hardware was micro-computers with CP/M operating systems and later it was PC's. Software items were developed for accounting, milk production control and feed planning, pig production control and forecasting, egg production control, and crop production control and planning. The business idea was that the branch in question of the farmers' organizations should be responsible for the subject matter content of the software, and the Agricultural EDP Centre for the development and coordination between various software items. The advisors of the farmers' organizations should give support to the users. There were also other suppliers of hardware and mainly accounting systems.

Software items bought by on-farm computer owners

Software	% buyers of potential users
Accounting systems	97
Milk production systems	40
Pig production systems	40
Crop production systems	11
Spreadsheet systems	33
Word processing systems	49

Source: Öhlmér 1987 and 1989

In 1990 around 2.5 % of all Swedish farmers (or 7-8 % of the full-time farmers) have invested in on-farm computers according to statistics from the Agricultural EDP Centre and an estimation of its market share. A study of a randomized sample of 127 on-farm computer owners showed that they have bigger farms than other farmers and they are more educated. (Öhlmér 1987 and 1989). Almost all used the computer for accounting purposes, table 1. Less than half of the computer owners having milk or pig production have bought a software item for this production. Just above 10 % have bought crop production software. One third have spreadsheet software, which they used for budgeting and the rough calculations for planning purposes and decision support that they previously did on a piece of paper. Half of the computer owners used a word processing system.

The comprehensive use of computerized information technology within agribusiness meant that a lot of information of interest for farmers was available in the main frame systems. In order to simplify the access to this information the Agricultural EDP Centre introduced a videotex system in 1984. The user invested in a cheap terminal or additional equipment to a PC. The system was accessed via the ordinary telephone links. The information offered from the

main frame systems was, e.g., results from milk production control, dairy cow data, bull data for breeding purposes, and bank account data. It was possible to order production means, insemination services, and bank services. Special information was added to the videotex system such as local weather forecasts and crop protection information. Around 1000 farmers were connected to the system in 1988, i.e., 3 % of the full time farmers.

The farmers' interest of the videotex system was judged to be too low to motivate the costs of the system, so the system was closed down in 1989. The system did not save any costs for the agribusiness, because other communication channels had to be kept parallel to the videotex system.

Data are communicated from computer systems in agribusiness to on-farm computer systems in order to automate the data collection. Examples are milk yield data, milk quality data, and slaughter data. Diskettes are sent by mail, which is the cheapest method at low number of users.

Sensors, memories and other electronic devices are built into farm machinery and building equipment such as feeding systems, tractors and combines. It is possible to connect these electronic devices to PC's for automated data collection to management information systems. Hardware and software for this is developed and tested both at the University and the Agricultural EDP Centre. However, it is not implemented on farms because of the small market.

Research and teaching

The use of computers in agricultural research started in 1961. Economic models were optimized with linear programming. The computer was situated at Uppsala University, and the Swedish University of Agricultural Sciences has used the main frame computers at its neighbour university in Uppsala since then. In 1965 the agricultural university bought the first computer of its own, a CD 8090, but most of the processing was still done at the bigger computers of Uppsala University.

In the middle of the 1970's the researchers began to use terminals and interactive processing. The number of terminals increased continuously and in 1987 there were around 500 terminals at the agricultural university in Uppsala.

Microcomputers began to be used in the beginning of the 1980's. In 1990 almost every researcher has a PC or Mac of his own. They are used for local processing and as terminals to main frame computers.

The PC's are integrated in the teaching at the university. The students are also typing their papers and dissertations by themselves with word processing systems. All farmer schools are using PC's in the teaching.

Factors affecting the demand and supply of agro informatics

General trends in the use of agro informatics

The increasing knowledge about breeding methods in agribusiness and optimization methods in research created a need to increase the capacity of the information systems. The technological development made this possible. The new technology saved labour costs and time. When the new technology became familiar new areas of use were found successively. The processing and storing capacities of the hardware increased and the price of a given capacity decreased, which made it profitable to computerize more and more.
The price of a main frame computer was, however, at such a level that it encouraged cooperation. The technology became available for a single, small user first when the PC's were introduced.

The technological development resulted in a shift from mail-in batch operated systems to terminal operated systems with remote batch or interactive processing. The quicker and more direct access to the information saved time and labour, and reduced the risk of error.

On-farm computer owners are doing accounting, performance control and some planning tasks by themselves, which they had hired service organizations to do. The storing and processing of data have been moved to the farm, but the same methods are used, i.e., the same information is produced.

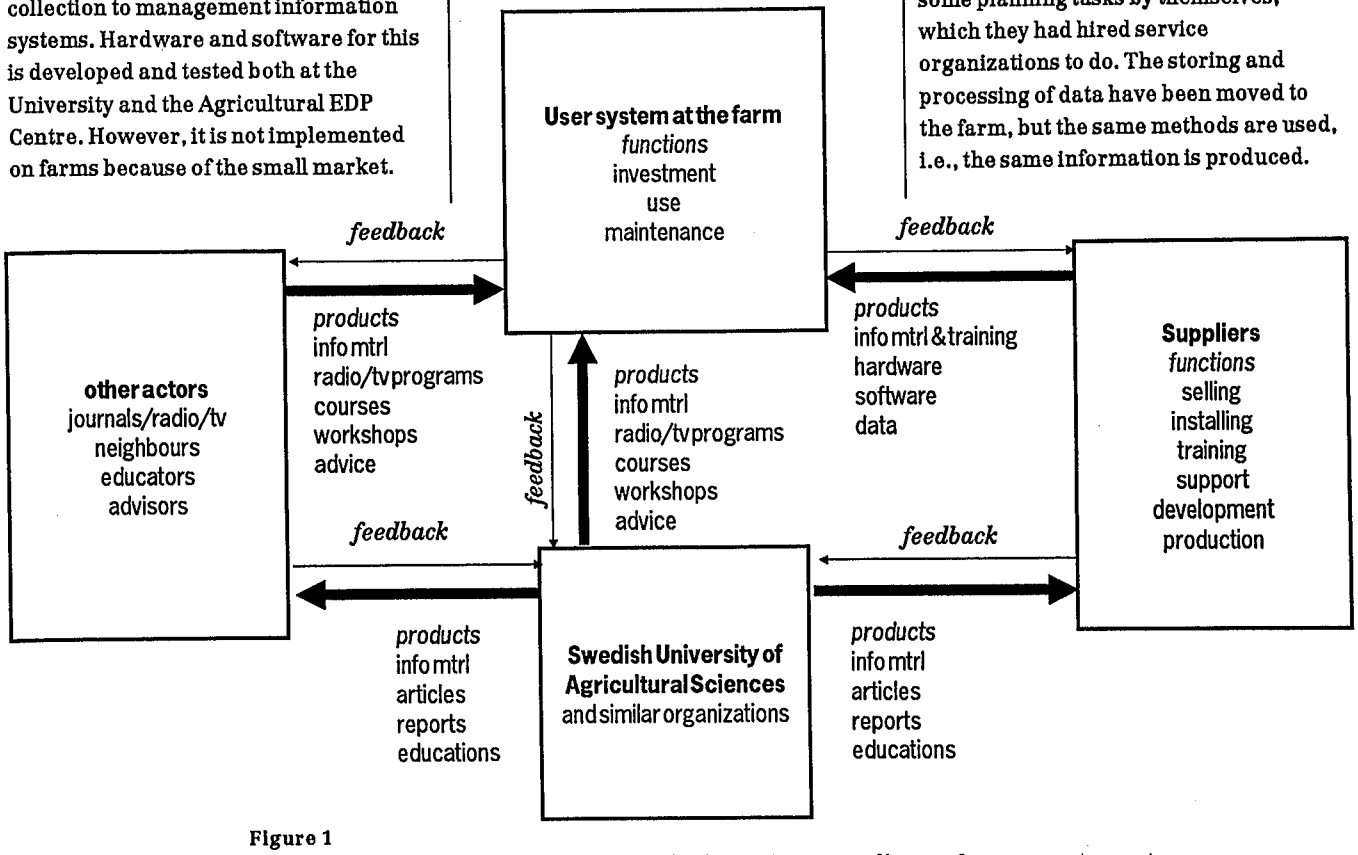

Figure 1
Relations between the farm, suppliers and other actors regarding on-farm computer systems

However, the own activity gives a better understanding of the information. The on-farm database gives a better availability of the information and a potential for automation of the data collection, which probably will be the next step in the development.

Organization of the supply and use of agro informatics

An information system for management purposes consists of:

- Hardware
- Theories, models and methods
- Delivery and service subsystem
- Use system

The hardware or the equipment may be as simple as pen and paper, or it may be a computer. In this context, where we discuss advanced information technology, we are interested in computer hardware.

Data are processed to information with the aid of theories, models and methods. In computerized information systems these are included in the software.

The delivery and service subsystem consists of, e.g.,:

- Marketing and providing introductory information about how to use hardware and processing models (software)
- Maintenance of the processing models (software) and hardware
- Organizations providing information, service and other support to the users
- Feedback information from users to suppliers

The use system is the system of collection and storage of data and processing data to information (e.g. reports) to be used in decision making and control.

The components of information systems in agribusiness were all developed (or provided) and used within the same organization. Then it is easy to organize the development and use of the system. It is more difficult in small organizations such as farms, where many suppliers develop and provide the components. Figure 1 illustrates the relations between the organizations involved in an on-farm computer system.

The Swedish University of Agricultural Sciences and similar organizations provide knowledge about the theories, models and methods needed in the software. The knowledge may be built into software, but then it mostly is software for research purposes. This activity is mainly paid by the government.

The biggest supplier of hardware and software is the Agricultural EDP Centre. It has around 60 % of the market. Computer shops sell hardware and accounting software. Some farmers have made software of their own, which they also sell to other farmers. Some of the data needed in the use may be provided by separate suppliers such as laboratories. The user, i.e. the farmer, had to pay the costs either directly or indirectly.

Some of the hardware and software suppliers and other actors such as farm journals, advisors and neighbours provides products of the delivery and service subsystem. Normally the users pay the costs, but some products are subsidized by the government (e.g., courses and workshops) and some are paid by the supplier (e.g., advices from neighbours).

Factors affecting the demand and supply of on-farm computer systems

The technological development and the decreasing hardware prices have been important forces driving the on-farm computerization.

The on-farm computer owners need knowledge about how to operate the computer system. Experiences from teaching computer knowledge to farmers show that this knowledge is easy to acquire. The users require 1-2 days of learning per application program to get started and the same for the system software (Öhlmér 1989). The increasing private use of personal computers will make it even more easy to learn the needed computer knowledge.

The on-farm computer owners used to hire service organizations for accounting, performance control and some planning tasks. Now they are doing these management tasks by themselves. Thus, they had to have the same knowledge level in farm management as the earlier hired service agents and advisers. An empirical evidence for this conclusion is that more than 60 % of the Swedish on-farm computer owners have the same higher education as the service agents and the advisers.

The same tendency is shown in a survey of 52 Canadian farmers using on-farm computers, where 74 % had education from college or university (Brink and Josephson, 1986). Putler and Zilberman (1988) have also shown that the education level of farm operators is an important factor (together with farm size) explaining the adoption of computer technology in Tulare County, California. They studied 115 on-farm computer owners and 75 % had a bachelor's degree or graduate degree. Other studies have reported that additional education increases the capacity to use computer provided information (Welch 1970, Schultz 1975, Huffman 1977).

The high knowledge level needed to use computer-provided information is an important factor explaining that the adoption rate is low despite that almost all computer owners (93 %) are satisfied with the on-farm computer system. It takes time to learn the needed management knowledge, so the adoption rate will be low in the future too. The demand of education and advisory service will be high.

The cost of software development is high and increasing. However, the computer owners are buying user licenses for standard software, and the prices depend largely on the number of buyers. Farmers can use the same standard software for accounting, spreadsheet calculations, and word processing as other managers of small firms. The number of buyers of these products is high and the prices are low. The number of buyers of the agricultural enterprise software is low, however, because of the low adoption rate within agriculture. The high development costs have to be covered by a low number of farmers. Difficulties to set the prices high enough mean that the supply of software items will be small.

A fact that may affect the software supply positively is that other benefits in the supplier's business may partly cover the development costs. The computer owners have the biggest farms and they produce a large part of the agricultural production in Sweden. Software items, services, support and similar may be a competition means in selling farm inputs and buying farm products.

Research and development in Agro Informatics

The theories and the knowledge behind the models and methods used in the information systems are primarily developed in research either in Sweden

or abroad and imported. The Swedish University of Agricultural Sciences has a key role in this process.

The computer hardware and the programming technology are developed outside the agricultural sector. The latest technology is used at the agricultural university in the development of knowledge about management. Decision support systems, management information systems, financial systems, monitoring systems etc. are developed as a part of the knowledge development. The agricultural university has no discipline of agro informatics, but it has a discipline of farm and business management that includes the use of information technology for management purposes. It has also a discipline of agricultural extension, which includes advisory methods and the transfer of knowledge from the university to empirical use.

The agricultural university has developed (or imported) many computerized models and methods for research purposes, and these models and methods form a research frontier. Some of them are too advanced to be used in practice, some are used by the advisors and in agribusiness, and a few are used by the farmers. The university does not have the resources needed to provide services and other support to the users. The researchers in question go on to the next research project and cannot devote too much time to support "old" models and methods.

The Agricultural EDP Centre has high competence in information technology and resources enough for a long term engagement. However, the alternative values of the resources are high and the costs have to be paid either directly by the farmers or by their organizations. The organizations are willing to pay only if it is profitable, or if they have other benefits that will cover the costs.
International cooperation in this field will facilitate the research and reduce the development costs. It is a way to increase the use of agro informatics and make the agriculture more efficient.

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Agro Informatics in the United Kingdom

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Introduction

In the UK the agricultural industry started to use computers in the mid-1960's mainly in those organisations which have a need to process large amounts of data. These organisations established data processing (dp) centres and included the Ministry of Agriculture, Fisheries and Food (MAFF) which processed a large volume of agricultural census data. Many other commercial and commodity organisations also had dp centres which were concerned with the internal operations of the organisation.

Some dp centres provided services to farmers on a post-in/post-out basis. In the main these were enterprise recording services covering the livestock sector. The management reports which were produced gave a month-by-month historical analysis of the performance of the enterprise. The introduction of the computerised analysis meant that many efficiency and performance indicators could be calculated. Later these services were developed to provide short term forecasts of future performance. The computers were also used to analyse farmers accounts and similarly to