A taxonomy survey of decision support systems in agriculture

B. Manos[1], A. Ciani[2], Th. Bournaris[1], I. Vassiliadou[1], J. Papathanasiou[1]*

Abstract

This paper presents the results of a research concerning the type, category and fields of applications of Decision Support Systems (DSS) and their contribution to decision-making in agriculture, mainly in the fields of planning and management of farms, farm regions and agricultural resources.

More specifically, the paper includes a taxonomy survey that has been based on an analysis of all published works on applications of DSS from 1987 to 2001, as well as a categorized presentation of these applications. The relevant classification of DSS is made by treating subject (theoretical DSS or applicative), the source of publication (proceedings, scientific journal or dissertation), the type of DSS (Decision Support System, Expert System or Knowledge Based DSS), the operational research model that each one DSS uses, the operational field (Diagnostic–Forecasting, Advisory, Control, Educational–Informational, Operational), the category of decisions (Strategic or Tactic planning decision) and the year of application.

The basic concepts and characteristics of DSSs along with the important role that they play in the decision-making process in agriculture, are also described at the beginning of this paper.

Key words: *Decision support systems in agriculture, Taxonomy survey, Decision making in agriculture*

Decision Support Systems

Decision Support Systems are computerized systems, which include models and databases and they are used in decision-making. They are "tools" that help farmers and everyone who makes decisions, in the procedure of decision-making and in choosing the best alternative solution from the economic, social or environmental point of view.

Several scientific sectors support the development and constitute the necessary background for effective planning of DSSs. The Science of Informatics contributes to the planning and the application of DSSs with the supply of the necessary tools, materials and software. The Sciences of Operational Research and Management and Business Administration provide the theoretical frame for the analysis of various decisions. The sciences of Behavior, Sociology, and Management of Human Resources, constitute

* 1. Department of Agricultural Economics, Aristotle University of Thessaloniki, 54006 Thessaloniki, Greece, e-mail: manosb@agro.auth.gr
2. Department of Rural Appraisal and Farm Accounting, University of Perugia, 06121 Perugia, e-mail: ciani@unipg.it
Correspondence: Professor Basil Manos, Department of Agricultural Economics, Aristotle University of Thessaloniki, 54006 Thessaloniki, Greece, e-mail: manosb@agro.auth.gr

sources of information that concern the manners in which the human potential behaves at the treatment of information and the decision-making process (Sage 1991).

A new approach in the process of decision-making constitutes the so called Expert Systems (ES). It is about special software that has stored the human experience in special subjects (e.g. diagnosis of illnesses) and makes the computer capable of providing artificial intelligence and acting as a type of Expert adviser (Manos 1989).

The combination of an ES and a DSS results to an Intelligent Decision Support System (IDSS) or a Knowledge Based Decision Support System. The IDSS can be used in order to summarize the running information and to present it to the users/decision makers as models and rules, providing support to the Agronomists of Rural Extensions, the farmers and the advisers of them.

"Support" is the keyword in the conceptual frame of these systems. With the utilization of them the role of decision makers is limited in the evaluation of results of mathematical models by which the decision can be made. The accent consequently is given to the support of decision maker and not in his replacement by the DSS.

a) Decision Support Systems Structure

A typical DSS, according to Sprague and Carlson (1982) and Manos and Voros (1993), comprises from the following components (Graph 1):

1. The Data Base and the Data Base Management System (DBMS)
2. The Model Base and the Model Base Management System (MBMS)
3. The User Support Base and User Support Base Management System (USBMS)

The Data Base contains all the data that are required for the DSS operation. The total of software that is used for the systematic management of them (storage, updating, retrieval and maintenance) constitutes the Data Base Management System.

The Model Base contains all the methods, techniques and models that are used for the data processing of the Data Base, on the analysis of problems and the output of final results. The transformation of data to information - results, which support the user/decision maker, is performed by the Model Base Management System.

The User Support Base is responsible for the communication of user/decision maker with the DSS. The input of data into the Data Base, the processing of them and the presentation of results to the user is performed by the User Support Base Management System.

Data Base and Data Base Management System

The Data Base constitutes an essential tool for the organized storage of data and information aiming at the easy renewal, correction and their utilization in every type of analysis (Manos 1989). These operations are performed by the Data Base Management System.

Depending on the particular technique of presentation, organization and storage of data, Data Base Management Systems are distinguished in three general categories (Manolopoulou 1994), (Zoubounidis *et al*.1996).

- Relational DBMS
- Hierarchical DBMS
- Network DBMS

In Relational DBMS, the structure of data includes sets of fields, which are related between them (Relational presentation of data). Each relation can be considered as a table, each line of which is a record, while each column (which is named attribute) constitutes a field, which also includes the correspondent space of values.

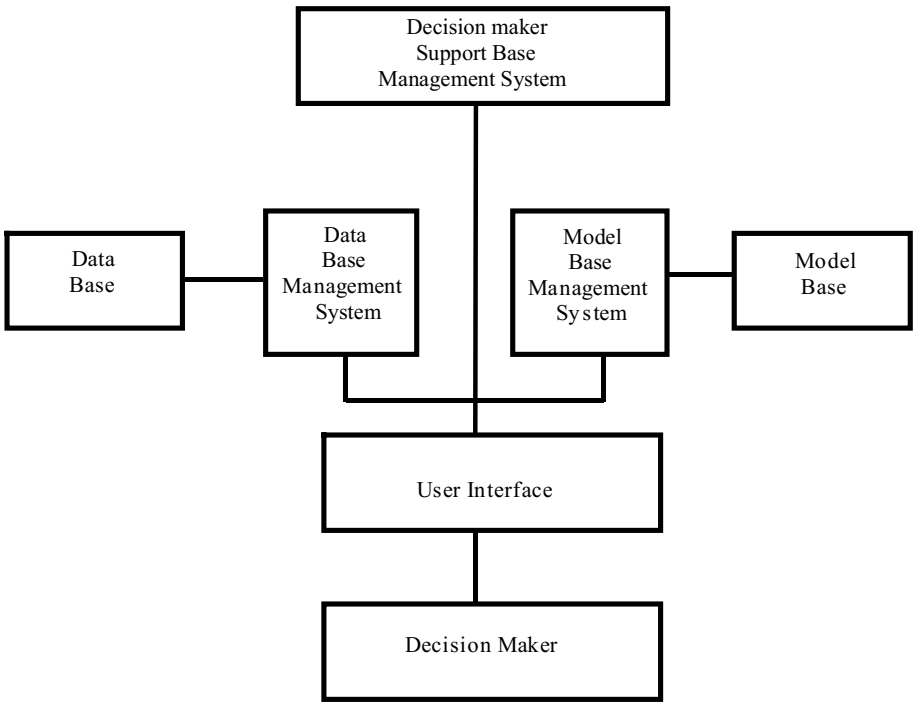

Figure 1. A typical Decision Support System

In Hierarchical DBMS, data are structured hierarchically from the most general to the most specific (Hierarchical presentation of data). Each level of hierarchy is constituted by a total of records, on which the immediately inferior level of hierarchy is developed.

In the Network DBMS the presentation of data becomes via a network, which is constituted by a set of records. The records are connected between them via links, which represent the relations between the records.

The Model Base and the Model Base Management System

The Model Base in a DSS includes mathematical, economic and statistical models, as well as models of Operational Research, capable to analyze problems and support the process of decision-making. Each one of models is run and is controlled by the Model Base Management System. The models execute simple or specialized operations and give operational, strategic or tactic decision support.

In a typical Model Base Management System the following methods and models for problems analysis are included, which support the interpretation of analysis results, in-

cluding also evaluation, selection and application of alternative solutions (Sprague and Carlson 1982), (Anderson *et al* 1994):

The Mathematical Programming Models: they are used widely for the resolution of problems as organization of farm enterprises and regions and generally the allocation of resources under restrictions, the planning and various similar applications. A lot of models of Mathematical Programming have been developed as Linear, Non Linear, Integer, Dynamic and Multiobjective Programming.

The Network Models: they concern the presentation of a problem using a graph, which is constituted by circles that are named nodes, connected between them with arrows

The Queuing Models: models that are used for the study, analysis and forecasting of systems behavior, the performance of which is related with queues.

The Simulation Models: models that require the use of a personal computer to present the development of a phenomenon in an environment that simulates the real world.

The Decision Analysis Method: this method constitutes a general approach of evaluation and choice of various alternative solutions, in conditions of uncertainty or risk.

The Markov Process Models: these models were drawn for supporting a general strategy of a system in which the changes in a period of time can be described as result of stochastic events.

The Analysis of Heuristics Process (AHP): it concerns any not algorithmic method of problems solution, in which the way to an acceptable final result is based on a course of approximate results.

The Forecasting Methods: techniques that are used for the forecasting of future orientations of an enterprise.

The Inventory Models: these models are used for the confrontation of problems of double aim, the maintenance of sufficient stock quantities, so that the demand of goods is covered, and which simultaneously achieve the minimum storage cost.

The User Support Base and User Support Base Management System

The User Support Base and User Support Base Management System defines the interaction between the user/decision maker and the DSS, influencing in important degree the output, the flexibility and manageability of the DSS

The main techniques that are used for the communication between the user/decision maker and the DSS are the followings (Zoubounidis *et al*.1996):

1. Communication in the form of questions - answers
2. Communication in the form of commands
3. Communication via menu of choices

In the case of communication in the form of questions - answers, the DSS puts questions to the user/decision maker, to which he must answer in order the DSS to draw the required information for the support of decisions.

In the case of communication in the form of commands, the user/decision maker communicates with the DSS via a language of commands, keyboarding the commands, which are usually composed by a verb and a noun.

The form of communication via menu of choices is friendlier and is dominated in the most DSSs because it gives the possibility to the user/decision maker to choose between

various menus the commands instead of keyboarding. The choice of commands is accomplished usually by the use of a keyboard or a mouse.

b) Expert Systems Structure

In an ES we distinguish the following five parts, accordingly with Siderides (1991), Gialouris (1996), Zoupounides *et al*. (1996):

1. The Knowledge base
2. The Inference engine
3. The knowledge acquisition and Knowledge representation
4. The interpretation part
5. The user interface

The Knowledge Base concerns the space of a concrete problem and represents the knowledge and the logic that an expert follows in order to be led to a conclusion.

The Inference Engine constitutes the part of an ES that undertakes the process of searching the Knowledge base for decision making. Through the mechanism of user-engine, it puts the questions to the user, receives the answers and applies them to the Knowledge Base.

The Knowledge Acquisition and Knowledge Representation is responsible for the interior representation of knowledge in the Knowledge Base. The main ways of representing the knowledge are the followings:

- The rules: are used for the correlation of simple facts with a decision. The principle of rules is based on the correlation of one or more with one or more results that are activated or considered as true, when all treaties are true.
- The semantic networks: are constituted by a set of facts that correspond to the nodes of a network. Nodes are connected between them with links and constitute thus a network. With the connection of nodes a correlation is also fixed between them. With this way the hierarchic structure of problem facts is achieved.
- The frames: a frame contains information that accompanies an object. That information, which contains values or indicators to different frames or rules or processes, from where the values corresponded to information and relevant with the object are drawn, is placed in a slot.

The Interpretation Part which by using the knowledge, stored in the Knowledge Base, gives to the user the answer because the system addresses a concrete question or it leads to the export of conclusions on a concrete problem.

The User Interface is responsible for the process of communication between the user and the system, for the benefit of explanations of the ES and the presentation of results to the user.

In agriculture the ES can be applied in diagnosis and treatment of plant or animal diseases, in classification of soils, in choosing the suitable mechanical equipment or animal capital, in farm management and regional planning etc. (Manos 1989).

The ESs are classified in general into the following categories (Gialouris 1996):

- Diagnostic-Prognostic ES: They support sectors as Plant pathology, Microbiology, Genetic, Agricultural Meteorology, and Soil Science.
- Operational-Control ES: They support sectors as the Agricultural warnings, the Agricultural Economy, the Underground Waters, the Irrigation Networks.

- Advisory ES: They support sectors as the Agricultural Economy, the Genetics, the Entomology, the Forest Protection, and the Cultivation Improvement.
- Shorting ES: They support sectors as the Soil Science, Systematic Botany, the Entomology and the Microbiology.

c) Intelligent Decision Support Systems Structure

An IDSS includes a combination of the basic components of a DSS and an ES. Consequently, in an IDSS we distinguish the **Data Base** and the **Model Base** of a DSS and the **Knowledge Base** and the **Interpretation Part** of an ES. Another basic component of an IDSS is also the **User Interface and Management System**, which is necessary for the interaction of individual parts and for the communication between the user and the system.

The interaction of basic parts in an IDSS is presented in the following Graph 2 (Zoubounidis *et al*.1996).

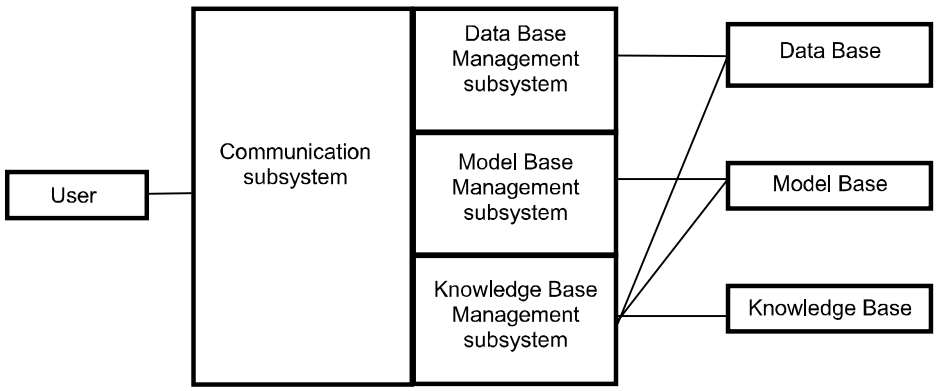

Figure 2. Structure of an Intelligent Decision Support System

d) WWW- based Decision Support Systems

The DSSs that are developed through the World Wide Web (Internet) are included in the category of WWW – based DSS. They are feasible and low cost solutions, which are used increasingly with the client/server structure for access, analysis and distribution of information that are stored in relational databases, through the On - Line Analytical Processing (OLAP) (Eom *et al* 1998). The Internet has given the opportunity of planning and development for these DSSs that are related with different subjects of interest.

The typical structure of a WWW - based DSS is presented in Graph 3.

A browser is the mean of access of a user into the system. The user puts questions, which subsequently are sent by the browser, into a hypertext file form. The system searches, analyzes and processes the data which are stored in relational data bases, and distributes them to the users.

The Decision-making Process in the Agricultural Sector

The Agricultural Sector, under the pressure of free competition and the limited production factors, is called to increase the competitiveness of the products and to develop the available production factors. The development of the Agricultural Sector up to date was associated with the import of new technologies, the use of new plant varieties, new animal races, fertilizers and chemicals, the application of new systems of cultivation, but mainly with the increase and extensive use of machinery. Today, the International competition indicates the necessity of rational management and production planning, consumption and agricultural products marketing, as it concerns motions that are interlocked in every agricultural economy. In the context of globalization of market and trade, the decision making, at farm or regional level, is highly depended on information and data (like research results, information about the market structure etc.). So the obtainment of information and data in agriculture is connected with decision-making, as these are necessary to come to a result.

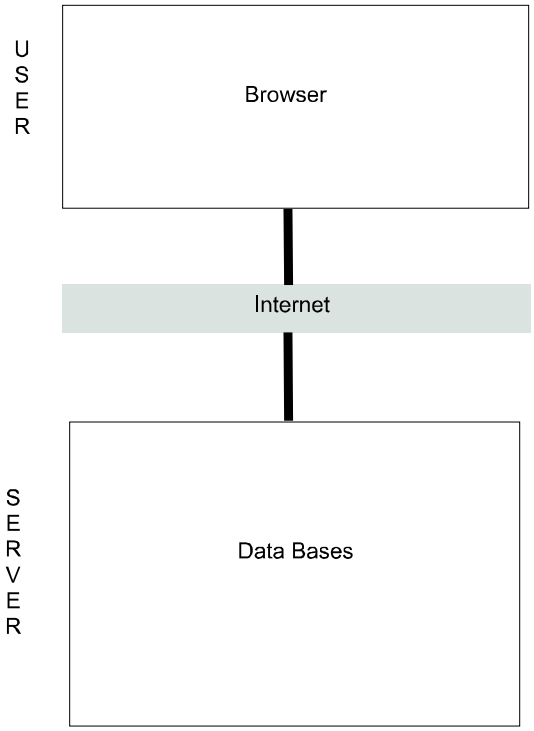

Figure 3. A typical structure of a WWW - based Decision Support System

The process of decision making in the agricultural sector includes the following stages (Anderson *et al*. 1994):

1. Localization and determination of the problem
2. Definition of the alternative solutions
3. Determination of criteria of evaluation of alternative solutions

4. Valuation of the alternative solutions
5. Selection of the alternative solution

The process of problem solving, for which decision making is required, includes moreover two different stages: the implementation of the selected alternative solution and the estimation of the obtained results (Anderson *et al*. 1994):

The decision-making process, in simple cases, includes the selection of solutions, of which the result is beforehand known and is based on standard and simple rules. However, in most cases, decision making is not based on explicitly defined rules but on knowledge, information, experience and on the skill of producers. Under this framework, we separate them in structured and unstructured decisions.

Structured are the decisions that are made on the basis of explicitly defined rules. It is about routine decisions, which represent one and only specific fact. As an example of a structured decision we refer the payment of wages of workers.

Decisions that are not made on the basis of explicitly defined rules, but they are based on knowledge, experience and on the intuition of the decision maker constitute the unstructured decisions. An example of an unstructured decision is the diagnosis of plant diseases.

There are decisions that are supported by defined rules, but the final action is not explicitly defined and it depends on different elements that the decision maker has into account. This type of decision is named semi-structured. Example of a semi-structured decision constitutes the selection of cultivating varieties.

A different classification of decisions is given by Kay (1986). According to this approach the agricultural decisions are distinguished into Strategic and Tactic planning decisions of farm enterprises.

The Strategic Planning Decisions are related with the selection of long-range objective targets. In consequence the time horizon of decision making is long and there is a wide view in development, enlargement and planning for farm enterprises.

The Tactic Planning Decisions are related with the daily decisions, which a farmer is usually called to make, when he faces up changes that embroil the management of farm enterprises, without these changes to infect necessarily in different sectors of economy. The time horizon of decisions is small, and they concern not planned choices.

Analysis of Published Applications of DSSs

a) Methodology

This part contains the analysis of results from the search in journals and other relevant publications for DSS applications in agriculture during the period 1987-2001. For our purposes we have used the following sources:

- The Data Bases Agricultural Economics (AgrECON), Agricultural Literature (AgrLit) and AGRICOLA,
- The Data Bases «INSPEC», «COMPENDEX», «CAB ABSTRACTS», «DISSERTATION ABSTRACTS»
- The search engines Webcrawler and Altavista of World Wide Web and
- The Greek Data Base "National Archive of Ph.D. Dissertations".

Congener researches used for article search in the INSPEC Data Base, which is the most popular Data Base in the DSSs field.

We found 363 publications. The analysis of 159 publications (percentage 43,8%) was based only on their abstracts.

For better processing of our search results, we classified the examined publications in two main categories, theoretical and applications.

1. Theoretical publications contain all the articles that give explanations and describe the meaning of DSSs, present general ideas and give the methodological and theoretical frame of development and planning of DSSs.
2. Applications contain the publications that give full description of unstructured or semi-structured decisions of Support Base Management System between the user and the DSS through the process of decision making.

Table 1 presents the frequency of appearance of the above mentioned categories in a total of 363 publications on DSSs, sorted by treating subject. The theoretical publications are 140, a number that corresponds to 38,6% of the total of publications, while the applications are 223 and they represent the majority of the total of publications (61,4%).

The basic sources of theoretical publications and applications are separated into three categories: a) scientific journals, b) Ph. D. and M.Sc. dissertations and c) congress proceedings. From the data of Table 2 infer that the publications in congress proceedings are the majority, 178 publications or 49,0%, the articles in Scientific Journals follow with 33,6% and last are the dissertations with 17,4%.

As the main objective of this research was to find the **applications** of DSSs in the Agricultural Sector, we proceeded with further analysis only on the 223 publications of the total of 363. However, it is important to note that the majority of the theoretical publications, specifically the 61,4% of them, describes the development and planning frame of the DSSs, 47 of them, i.e. the 33,6%, describe the development and planning frame of the ESs and the rest 5,0% the development and planning of the Knowledge Based DSSs (Table 3).

b) Models used in Decision Support Systems

The Operational Research Models comprise main elements of the DSS, as described in Table 4. The number in the second column refers to the frequency, in which every technique appears in the 363 published articles of our research.

We see in this table that the Simulation Models possess a major position in the investigation of the problems supported by DSSs.

The Deterministic Models are also widely used in DSSs, as well as Network and Inventory Models, Dynamic Programming, Linear Programming and non Linear Programming models.

The Multi-Objective Programming is also used for the development of the DSSs and especially for the Multiple Attribute Decision Making.

Artificial Intelligence tools, such as ESs and Neural Networks, also present great frequencies.

c. Data Analysis

The majority of published applications of DSSs (42.1%) have been presented in congresses, as described in Table 5. A large percentage of them (32.7%) have published in

scientific journals and the rest 25.2% of them are presented in dissertations (M.Sc. or Ph.D.).

Table 1. Publications for DSSs in Agricultural Sector

Publication Categories	Frequency	Frequency (%)
Theoretical	140	38.6
Applications	223	61.4
Total	**363**	**100.0**

Table 2. Basic Sources for DSS publications in Agricultural Sector

Publication Sources	Frequency	Frequency (%)
Congress Proceedings	178	49.0
Scientific Journals	122	33.6
Dissertations	63	17.4
Total	**363**	**100.0**

Table 3. Subject of the Theoretical publications

Subject	Frequency	Frequency %
Decision Support Systems	86	61,4
Expert Systems	47	33,6
Knowledge Based DSS	7	5,0
Total	**140**	**100,0**

Table 4. Participation of Operational Research Models in development and planning of Decision Support Systems

Models	Number
Simulation Models	129
Artificial Intelligence	128
Multi-objective Programming	88
Network Models	74
Dynamic Programming	51
Query Language	48
Analysis of Heuristics Process	37
Inventory Models	26
Linear Programming	14
Graphics	14
Non Linear Programming	15
Total	**624**

Table 5. Main sources of the published applications of the Decision Support systems

Sources	Frequency	Frequency %
Congress Proceedings	94	42,1
Scientific Journals	73	32,7
Dissertations	56	25,2
Total	**223**	**100,0**

The 73 from the total of 223 publications are in journals of Agricultural and Operational Research Sectors. Table 6 presents the scientific journals of publications covered by our research.

Table 6. Sources of published applications

Scientific Journals	Frequency
Computers and Electronics in Agriculture	45
Agricultural Water Management	9
Agricultural Systems	3
Ecological Economics	3
European Journal of Agronomy	3
Agricultural Economics	1
Aqua cultural Engineering	1
Applied Mathematics and Computer Science	1
Computers, Environment and Urban Systems	1
Control Engineering Practice	1
Decision Support Systems	1
European Journal of Operational Research	1
International Journal of Geographical Information Systems	1
Mathematical and Computer Modeling	1
Radiation, Protection, Dosimetry	1
Total	**73**

For a better and substantial study of the total of 223 published applications, DSSs were separated, according to the field of specific application, in the following five classes:

1. In **Diagnostic - Forecasting** DSSs were included all systems that support the fields of phytopathology, the diagnosis or the prognosis of plant and animal diseases.
2. In **Advisory** DSSs were included all systems that estimate data and provide advices in Strategic or Tactic Planning Decisions of an agricultural enterprise or an agricultural region. The tactic DSSs are separated in Plant and Animal Production Administration Systems. More analytically, the Plant Production Administration Sys-

tems, were classified depending on the sector that they support in Soil Administration Systems, Nutritious Supplies, Management of Harvest, Management of Water Resources, Fruit Post-harvest Management and Standardization Support Systems of Rural Products.

3. In **Control** DSSs were included agricultural warnings as for the repercussions of agricultural reactions on the environment, underground waters etc.
4. In **Educational - Informational** DSSs were included all the systems that provide information and constitute educational tools for producers, Agronomists of Agricultural Extensions and Advisers.
5. Finally **Operational** DSSs include systems that provide help in enterprises that support the Primary Sector, as enterprises of rural products distribution, agricultural instruments etc.

Table 7 presents the frequency of appearance of published applications of Decisions Support Systems depending on the field of application. As we can see the Advisory DSSs possess the majority of published applications with a percentage of 59.2%, followed by the Control Systems with a percentage of 18.4% and the Diagnostic - Forecasting DSSs with a percentage of 14.3%. In the category of Informational - Educational Systems belong 12 publications, with a percentage of 5.4% and in Operational DSSs belong 6 applications, with a percentage of 2.7%.

Table 7. Classification by field of operation and frequency of Published Decision Support Systems Applications

Field of operation	Frequency	Frequency %
Diagnostic - Forecasting	**32**	**14.3**
Advisory	**132**	**59.2**
•Strategic Planning	88	66.7
Agricultural Regions	28	
Agricultural Enterprises	60	
•Tactic Planning	44	33.3
Administration of Plant Production	37	
Soil Management	7	
Nutritious Supplies	9	
Harvest Management	4	
Water Resources Management	11	
Fruit Post Harvest Management	3	
Farm Products Standardization	5	
Administration of Animal Production	5	
Control	**41**	**18.4**
Educational - Informational	**12**	**5.4**
Operational	**6**	**2.7**
Total	**223**	

The Advisory DSSs that provide advises in Strategic Planning decisions are double than them in Tactic Planning decisions. More specifically, 88 publications that correspond to a percentage of 66.7% of this category or percentage of 39.5% of the total of published applications, support decisions of Strategic Planning. From the total of 223 applications, a percentage of 19.7% concerns Tactic Planning Advisory DSSs. As shown in Table 7, these systems possess the 33.3% of published applications of the category of Advisory DSSs, in a total of 44 publications.

Table 8. Applications of DSSs depending on the field of application and the year of publication

Application Field	87	88	90	91	92	93	94	95	96	97	98	99	00	01
Diagnostic - Forecasting	1		1	2	5	2	3	3	8	5	1	1		
Advisory	3	2	3	5	14	11	16	16	18	22	9	7	4	2
Control			3	2	5	1		7	10	4	7	2		
Educational-Informational					1		2			7	1	1		
Operational					2	1		2		1				
Total	**4**	**2**	**7**	**9**	**27**	**15**	**21**	**28**	**36**	**39**	**18**	**11**	**4**	**2**

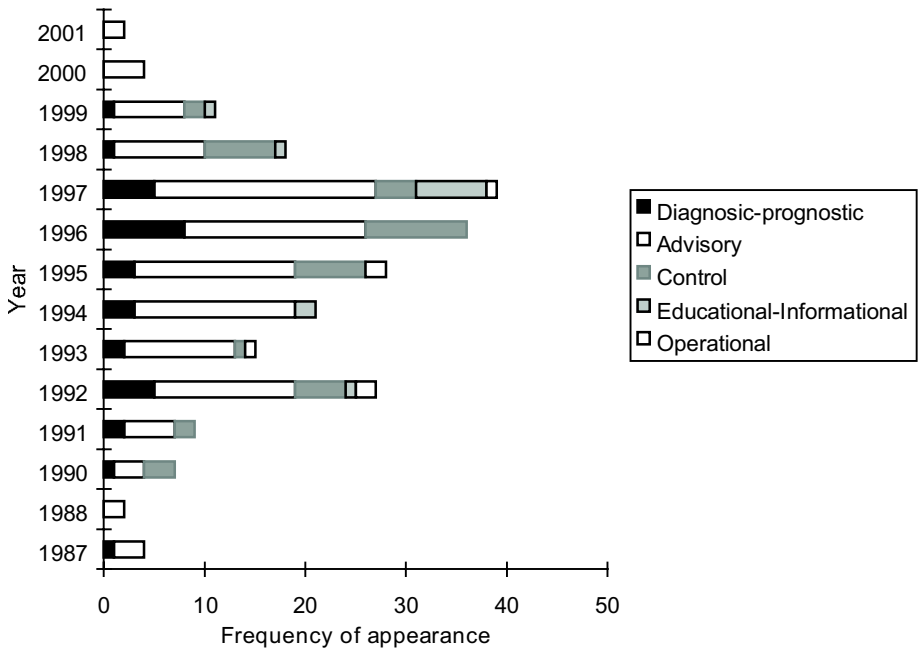

Figure 4. Classification of DSSs by the field of application and the year of publication

The distribution of DSSs by the field of application and the year of publication (Table 8 and Figure 4) shows an important increase of DSS applications between the years 1987-1997. From the same table we conclude that in the study period, the majority of published applications concern systems that support strategic and tactic planning decisions.

Conclusions

The planning and the development processes in the agricultural sector constitute a multi-complex problem that is difficult to be solved, if it is not faced thoroughly. The interdependence between the various production activities on one hand and between the services on the other hand is very high making their planning difficult. To draw conclusions and take decisions in agriculture is a process that is not based on stable, simple, and well-defined rules, but on knowledge, information, experience and skills of the producers/decision makers. Moreover, the decision making process demands from the producers/decision makers a qualitative evaluation and understanding of the problem that they are facing.

A DSS evaluating all the capabilities that the science of Informatics is providing, is capable of gathering and processing of all the economic and technical data that are necessary for the confrontation of the problem, so that the role of the decision maker can be limited only to the results evaluation, on which the decision making process will take place.

From the above presentation and analysis, we conclude that the DSSs have a wide application in decision making concerning problems of the agricultural sector with not well structure and complexity.

The majority of the published DSS applications concern systems that support strategic planning decisions; this means that they are connected with the choice of long run objective targets. A wide application also present the DSS that are related with agricultural warnings or/and control from the sequences of agricultural practices on the underground water and the environment, as well as the DSSs that support the diagnosis, prognosis and fighting off diseases that attack the crops.

Their application is due to the fact that they provide the ability of quick processing of vast volumes of data and they support the entire process of decision making, from the stage of planning to the stage of selection, and finally to the stage of implementation, making possible to the producers/decision makers to check the process of analysis of problems.

Whatsoever, the DSSs focus their interest on mathematical models and techniques, and on the way that these interact one to each other in order to produce more processed information, rather than on the way the producer/decision maker explicates and uses these information. For this reason, the producers/decision makers are usually restrained to the results of the used techniques and models of analysis. It is often for the DSS to lose their reliability, because the producers/decision makers are not familiar with their basic operational principles or because they do not have the necessary theoretical background in order to explain the results; so that the use of DSSs leads often them to wrong conclusions and estimations.

All the above mentioned require the attention of the DSS developers, as well as the agricultural extensionists; it is their responsibility to adjust the DSSs to the ambitions, the experiences and the living conditions of the producers/decision makers in order to have the required credibility.

References

Anderson, R. D., Sweeny, J. D. and Williams, A. T., 1994. An Introduction to Management Science. Quantitative Approaches to Decision Making. West Publishing Company.

Eom, S.B., Lee, S.M., Kim, E.B. and Somarajan, C., 1998. A Survey of Decision Support System Application (1988 - 1994). Journal of the Operational Research Society, 49, 109 - 120.

Gialouris, C., 1996. Artificial Intelligence and Expert Systems. Athens: Agronomical University of Athens. Department of Informatics.

Kay, R. D., 1986. Farm Management: Planning, Control and Implementation. 2nd ed. New York: McGraw-Hill.

Manolopoulou, E., 1994. Techniques for System Design and Analysis. 2nd ed. ANUBIS S.A.

Manos, B., 1989. Computers and their applications in agricultural economics. Thessaloniki Greece: ZITI.

Manos, B. and Voros, M., 1993. Standardized Methods for Improving Farm Decision - a Decision Support System for Poultry Producers. International Management Association :232 – 253.

Sage, D. A., 1991. Decision Support Systems Engineering. New York: J. Wiley.

Sideridis, A., 1991. Information Systems. Athens: Agronomical University of Athens.

Sprague, R.H.JR., and Carlson, E.D., 1982. Building Effective Decision Support Systems., Englewood Cliffs, New Jersey: Prentice - Hall

Zoubounidis, C., Doubos, M., and Machachinis, N., 1996. Multicriteria Intelligent Decision Support Systems for the Evaluation of the Performance and Viability of Enterprises. Athens: ELLIN.