DECISION SUPPORT SYSTEMS FOR FOOD AND AGRICULTURE

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Summary

The management of agricultural production operations can be complex and daunting. A manager who is faced with a decision confronts many factors that need to be simultaneously considered. In addition to facing a management decision that will potentially improve the immediate operation, the manager must ultimately be accountable to society and to the environment. The impacts of decisions go far beyond the farm. Decision support systems provide managers with recommendations for specific situations and help with analyzing choices. To better understand decision support systems, it helps to understand the meaning of systems and systems analysis. This chapter provides basic background on systems definition, systems analysis, and systems identification. It then provides description and examples of three types of decision support systems: qualitative-based expert systems, quantitative-based simulation models, and a combination qualitative and quantitative model.

1. Introduction

We are faced with decision making every day. From something as simple as deciding what to wear in the morning, to something as complex as deciding what career to follow, decision making invokes certain similar cognitive processes. Decision making is based on a combination of experience, empirical data, and analysis of the situation at hand. The process is diagrammed in Figure 1.

We make decisions based on a qualitative approach, a quantitative approach, or some combination of the two. A simple task may require only past experience and a bit of knowledge of the current situation to make a final decision. For example, deciding what to wear in the morning would require knowledge of the situation to be faced (going to work, day off, a formal occasion?), some general data (is it cold or hot outside?), and some past experience (these colors go together; this keeps me warmer when it is cold). However, more complex decisions with greater consequences may require experience, judgment, and quantitative analysis. The management of an agricultural process often combines experience with manipulation of hard numbers.

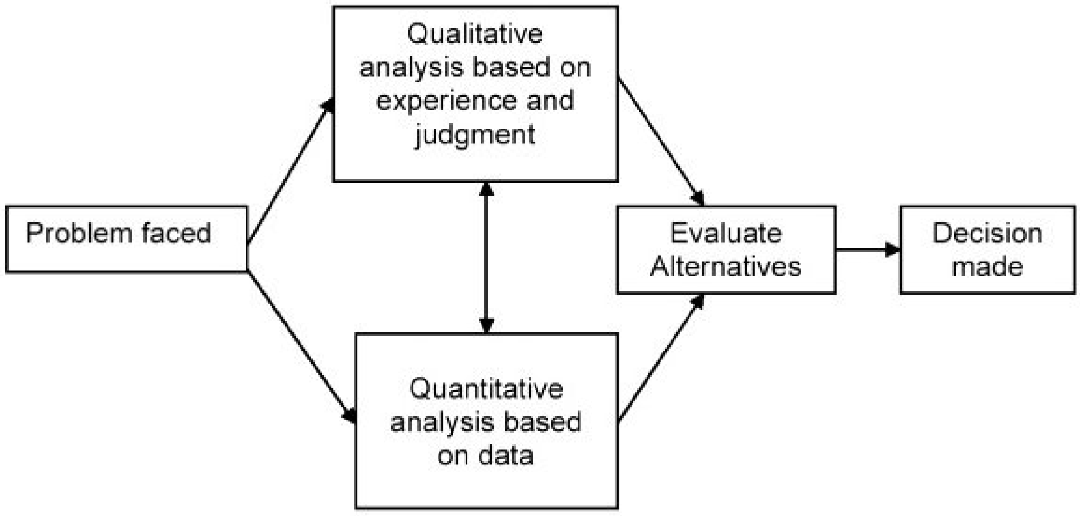

Figure 1: The decision making process.

A decision support system (DSS) is a computer-based program that assists with the decision making process. The program can be quantitative, qualitative, or a combination of both. These programs are important because agricultural production and processing systems are complex due to the many biological, chemical, and physical processes involved, and require a great deal of information to be processed for proper management. A tool that helps assist with the decision making process will reduce the amount of guesswork involved, as well as increase the likelihood that proper information is considered. These support programs are computer-based because in many cases, large amounts of data, as well as complicated calculations and numerical procedures, are required to provide high-quality and relevant decision recommendations.

2. Systems Definition and Systems Theory

To better understand decision support for managing agricultural systems, it is necessary to understand what is actually meant by a "system". A formal definition is nicely provided by Wright (Wright, R. 1989. Systems Thinking: A guide to managing in a changing environment, Society of Manufacturing Engineers, Dearborn, MI. 162 pp.):

"A system is an identifiable, complex dynamic entity composed of discernibly different parts or subsystems that are interrelated to and interdependent on each other and the whole entity with an overall capability to maintain stability and to adapt behavior in response to external influences."

This definition captures all of the key descriptions of a system. Of particular interest are the following words or phrases: dynamic entity, discernibly different parts or subsystems, interrelated to and interdependent upon, maintain stability, adapt behavior. "Dynamic" means that a system has motion or energy flow. "Discernibly different parts" means that a system is made up of identifiable components. One of the most important phrases is "interrelated to and interdependent upon", which is the essence of a system. The components work together to create the function of the system, and depend upon each other for proper function. "Maintain stability" means that a system will continue to function, even if it is at rest. Finally, "adapt behavior" means that a system has some reaction to inputs. This reaction can be as simple as a thermostat-controlled heater, or as complex as a proactive human.

2.1. Agricultural Systems

Using the definition described above, it is relatively easy to see that agricultural operations are truly systems. A broad view of agricultural systems is shown in Figure 2.

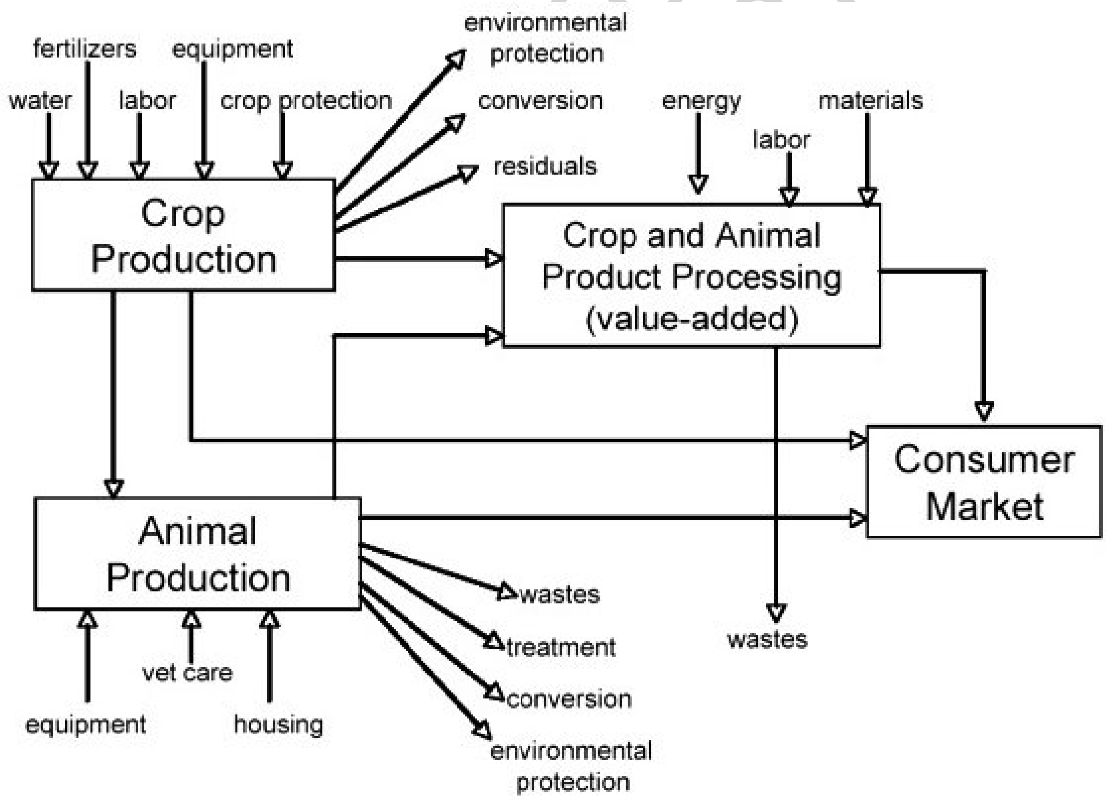

Figure 2: A broad view of agricultural systems (Spedding, C.R.W. 1988. An Introduction to Agricultural Systems. Elsevier Applied Science. London. 189 pp.).

Both production and product conversion (processing) are shown in this figure. Crop and animal production have inputs which are transformed to produce products. Each broad system (crop production, animal production, processing) is made up of interacting dynamic components and subsystems.

There are vast numbers of subsystems within agricultural production and processing. Each type of crop or animal product has its own set of interacting dynamic components upon which observations need to be taken, decisions need to be made, and operations need to be controlled. Examples include growth of grain crops in fields, ornamental flowers in greenhouses, milking of cows in dairy parlors, packing of fresh fruit, aseptic processing of juice, and canning of soup. There are literally hundreds of examples that could be given, but regardless of the example, the decision making process described earlier applies.

2.2. Systems Analysis Techniques & Decision Support

Systems analysis techniques provide the decision maker with tools to assess a particular operation. Most system analysis techniques are quantitative, relying on mathematical formulations and numerical input for proper execution. However, some techniques, such as expert systems, rely on the capturing of experts' judgment, experience, and logic processes. These types of decision support tools utilize qualitative input to come to a recommendation. Commonly used systems analysis techniques include optimization approaches such as linear and non-linear programming. Other approaches utilize simulation modeling and economic analysis.

A decision support system utilizes one or more of these tools to help with the decision making process. Which tools are used will be dependent upon the nature of the decision support system’s application area.

2.3. Structure of a Decision Support System

The basic structure of a DSS is shown in Figure 3. When a decision-maker is faced with a problem that can not be easily solved based on experience and judgment alone, the DSS is utilized. The DSS will ask questions that help determine the nature of the problem and the resources that need to be used. These resources may include quantitative modules (simulation, optimization), or rule bases (heuristics).

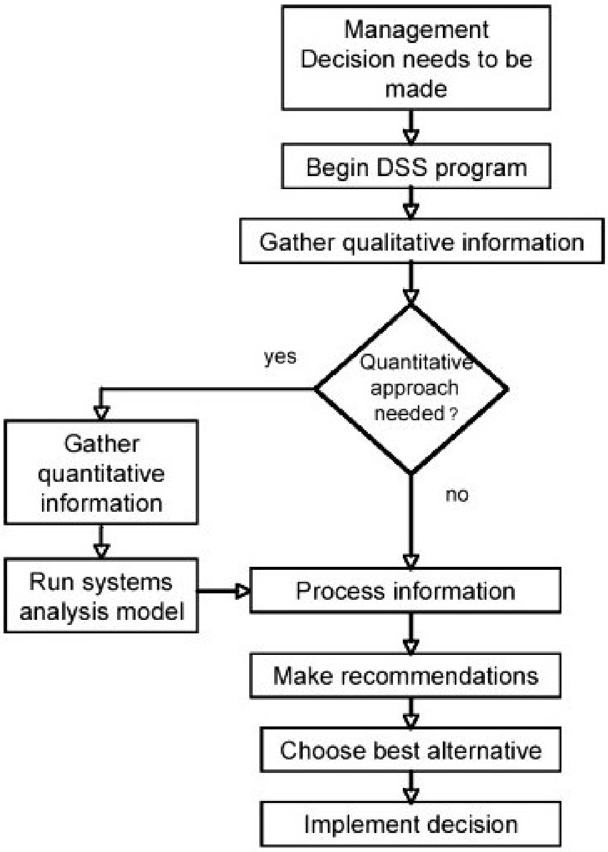

Figure 3. Basic structure of a decision support system.

2.4. Qualitative and Quantitative Decision Paths

If the DSS determines that the decision needed is based on experience, judgment, and heuristics ("rules-of-thumb"), the information gathering will be primarily qualitative. A DSS that processes non-numerical information to make a decision is called an "expert system". If a quantitative approach is needed, then the program may branch into a quantitative path that gathers numerical information for mathematical processing. Examples of quantitative techniques used in DSS are simulation modeling, to predict future outcomes, and optimization, to find the "best" solution for a particular situation. More details and examples of these types of DSS are found in the following sections.

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Biographical Sketch

Paul Heinemann is Professor of Agricultural Engineering in the Department of Agricultural and Biological Engineering at the Pennsylvania State University. He has been on the faculty since 1988. He teaches junior, senior, and graduate courses in systems modeling, optimization, and systems analysis. His research has included artificial intelligence techniques for agricultural production and processing (expert systems and neural network applications), simulation modeling, advanced sensors for produce quality evaluation and pathogen detection, frost protection automation, and mushroom production.