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THE INFLUENCE OF SEEDING RATES ON CROP YIELD IN A DSS FRAMEWORK: APPLICATION TO TWO ALFALFA CULTIVARS IN SUDAN

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Abstract: This paper presents a decision support system to support agronomists, stand on their ideas and helps them to determine the best level of seeding rate based on the data collected from their field's experiment. This study employs the split-plot algorithm of Gomez & Gomez (1984) under the framework of a decision support system (DSS). The DSS that automated the Split plot procedure, based on which the best seeding rate out of several rates of the agronomist's experiment is discussed in this paper. The DSS was also able to incorporate several cultivars in addition to the different seeding rates.

Keywords: *agricultural information systems, decision support systems, split-plot procedure.*

INTRODUCTION

The rapidly growing demand for - information technology applications have induced managers, farmers and policy makers to question the performance of their manual systems versus an automated versions of them. In Sudan, the information systems (IS) application started to grow in the last ten years. The IT applications to the agriculture and environment and the decision support systems (DSS) have unfortunately been stagnant and attracted very scarce attention (Siddig *et al.*, 2006).

Researchers in areas of agriculture, environment, and resource management are facing an extremely insufficient supply of information technology (IT) applications and computer software, particularly during the preparatory stage of their research experiment as well as the stage of analyzing their results. This cause huge losses in the researcher time and effort particularly after the design of their field experiments, and the collection of data, as well as during the stage, where they analyze their results and judge their findings. Due to the primitive methods used by the researchers in terms of

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manual calculations and comparisons; the obtained degree of accuracy and reliability, does not satisfy relatively international standards.

It is therefore the objective of this paper is to provide and discuss the components of a DSS, which was designed to tackle this problem. It ease the data entry process and improve the accuracy of calculations, while present the final results in simplifies and descriptive way that does not require a specific knowledge and skill in computer applications. The DSS follows similar steps as the manual analysis in order to convince the researchers that they are doing exactly the same work with more accuracy and less time

AGRICULTURE AND INFORMATION SYSTEMS

Many forces are driving increased interest in applying information technology to agricultural research and development. They represent both needs and opportunities, to increase the use of information technology (Bouma *et al.*, 1995). Perhaps the strongest demand comes from the recognition that diagnosing and solving problems at local or farm level often requires consideration of factors ranging from impact of specific pests, to local management of water resources to availability of off-farm employment. The boundaries of a problem solving activity thus are often much wider than would have been the case three decades ago (Bouma *et al.*, 1995).

Such "a system's approach " requires strong interdisciplinary collaboration, which in turn implies ready flow of data and information among stakeholders, a clear niche for databases, and internet access. Furthermore, to view interactions of systems components, systems methodologies often rely on computer–based tools such as simulation models and geographic information systems.

To evaluate the merits of the various IT tools and approaches, a review of potential users, types of information, and tools of analysis is required to illustrate and satisfy the diversity of needs and opportunities. Ideally, one might seek a comprehensive conceptual framework for IT applications to agriculture, but appears that the field is still too broad and dynamic to permit an effective synthesis (Kam *et al.*, 1998).

Potential users of IT application in agriculture range from decision-makers, who set the overall agricultural policies, down to individual farmers and consumers. Each group differs in its expectations, needs, and ability to access tools. We recognize six groups, but recognize that boundaries are often indistinct. The groups are policy makers, research managers, researchers, extension and development workers, farmers (and farm-workers), and consumers and the public. The growing emphasis on full participation of stakeholders in decision processes dictates that different IT users will meet and interact extensively. This suggests a need not only to consider users as distinct groups but also to view them as members of broader units with multiple types of users (English *et al.*, 1999).

Further demand for decision support system comes from the need to strengthen linkages between research and development. Many promising technologies are slow in reaching intended users, and perhaps worse, significant number of research projects addresses problems that extension service providers, farmers, or consumers ultimately identify as low priorities again, DSS offer numerous mechanisms for improved synthesis and interchange of information. Resource constraints are also driving research and development organizations to seek increased complementary among project information as well as improved justification and synthesis of research outputs. While the above points emphasize demand for decision support systems tools, increased use of information technology also offers tremendous opportunities.

Types of agricultural information

Information required in agricultural research and development efforts ranges from project description to specific results of field or laboratory evaluations to qualitative indicators or consumer perspectives. Information is the hierarchy of data, information and knowledge, better represents the spectrum used in agricultural research and development (Figure 1). Within "knowledge," a further distinction can be made between explicit and tacit knowledge.

Explicit knowledge can be expressed in a symbolic form (e.g., a written description or a mathematical formula), while tacit knowledge is the more subjective "know-how" that grows from professional experience. A more pragmatic distinction is between levels of allowed data access, which is gaining relevance given increasing concerns over intellectual property and privacy. Many information types can be categorized based on whether they are for shared or internal access. Importantly, most database and internet technologies allow filtering information by desired levels of user access (Neuman *et al.*, 2000).

DEVELOPMENT OF DECISION SUPPORT SYSTEMS

According to Shulthsis *et al.* (1997), a decision support system (DSS) is defined as an integrated analytical tool that describes key processes and spatial and temporal connections within and between human and biophysical subsystems from a systems perspective. It uses a multidisciplinary approach to provide a definitive representation of a system, using mathematical algorithms where

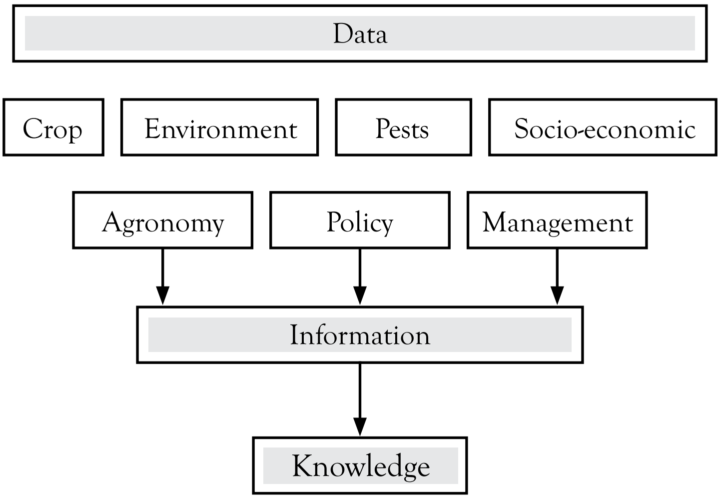

Figure 1 The hierarchy of moving from data to information and then knowledge. (Adapted from [Neuman *et al.*, 2000])

relevant. Multiple management objectives are recognized and built into the evaluation framework. A DSS comprises data sets, key analytical models, and a user interface, and is central to the agricultural decision-making process.

The development of a DSS requires an adaptive design process that involves the interaction of a user and builder with the information system. DSS development starts when a user identifies a problem area and begins to think of information that would contribute to an understanding of it. A model decision support system is built with close cooperation between a builder and a user. This DSS is designed by builder, tried out by a user, and continually modified based on the users' evaluation. This continuous or iterative process encourages short-lived system that can be junked when they are no longer needed and refined as the user's needs change (Shulthsis *et al.*, 1997).

Decision Support System for Agriculture Research and Development

While individual tools are useful, the value is multiplied when efficiently linked to required data and complementary tools to create DSS. Information technology provides the tools that allow us to systematically generate, organize and make knowledge available to those who require it most–passing it from the hands (and minds) of researchers to the "real" users of the land and natural resources, thus empowering people to manage their resources in more informed and rational manner.

Based on simple cycle of problem identification developing and selecting options and making decision, six functional categories of tools can be identified in a decision making process in Figure (2) tools for characterization include database and geographic information systems (GIS). Information

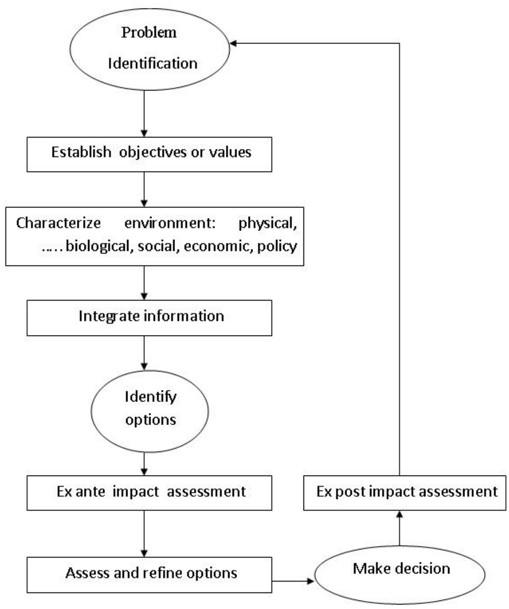

Figure 2 Useful tools in decision-making for agricultural research and development. (Adapted from [English, *et al.*, 1999])

integration functions may be built into these tools or provided through links to models or reporting tools (English *et al.*, 1999). Models, especial process–based simulation, and econometric models, play their largest role as tools for assessing consequences of scenarios, whether prior to adoption during planning phases (ex ante impact) or after adoption (ex post impact).

Farm Management DSSs

The need for more and better information on which to base decision is not a new problem. However, in recent years, this problem has become even more important, particularly for capital-intensive farming in industrialized countries (Wanger *et al.*, 1991). Information is required for different levels of farm management ranging from very short–term decision such as applying an insecticide, to very long–term decision, such as building a hog-barn. In addition, the information needs for the capital-intensive farming deviates from those extensive farming.

Capital-intensive farming is characterized by high sales volume in comparison to the generated net value added, e.g. layer hens or feeder pigs range cattle where the monetary input is high in relation to sales volume. Thus, in capital–intensive farming small changes in input-output coefficients and /or prices can cause net income to switch from positive to negative. Due to these facts, the inputs and outputs need to be monitored and controlled much more closely than in extensive farming. Therefore, the information required for capital-intensive farming needs to be on higher levels with respect to quality as well as quantity. Providing farm managers with better information has been an evolutionary process. These efforts include developing electronic data processing systems, such as linear programming, management information systems, and currently, decision support systems (Kuhlmann *et al.*, 2001).

MATERIALS AND METHODS

The DSS of this study is based on a field experiment, which was conducted at the Demonstration Farm of the Faculty of Agriculture, University of Khartoum at Shambat during the period between November 2001 and June 2002. The aim was to study the effects of seeding rates on growth and yield of two Alfalfa cultivars. Detailed description and documentation of the experiment's specification from the agronomic prospective are available in Abdel-Rahman (2003). The treatments consisted of four seeding rates (10, 15, 20, and 25 kg/ha) and two Alfalfa cultivars viz; the local cultivar Higazi and the introduced cultivar Siriver. They were randomly assigned in a split-plot design with four replications. The split-plot procedure will be defined and described in the next section.

The field experiment is focused on six parameters with respect to the components of the yield; however, for simplicity this paper focuses only on one parameter, which is forage fresh yield. Forage fresh yield is used as an indicator for crops productivity to compare the different treatments. The rationale of this study concentration on the forage fresh yield which represent the direct production, is that the study seeks providing a flexible kind of computer software that possess the ability of helping a wide range of researchers, regardless to the crop they are considering. This is important in the sense that, the production of other crops like grains is basically grain, therefore productivity can be only determined according to their final grain production.

Hence, their best seeding rate considers only their final output as an indicator.

Split-plot Design

The split-plot design is an experimental design that is specifically suited for a two factors experiment that has more than one treatment. That can be accommodated by a complete block design in split-plot design; one of the factors is assigned to the main plot. The assigned factor is called the *main-plot* factor. The *main-plot* is divided into subplots to which the second factor, called the *sub-plot factor,* is assigned. Thus, each *main-plot* becomes a block for the *sub-plot* treatments (Gomez & Gomez, 1984).

With split-plot design, the precision for the measurement of the effect of the main-plot factor is sacrificed to improve that of the subplot factor. Measurement of the main effect of the subplot factor and its interaction with the main-plot factor is more precise than obtainable with a randomized complete block design. On the other hand, the measurement of the effect of the main-plot treatments (i.e. the levels of the main-plot factor) is less precise than that obtainable with a randomized complete block design. Because, with the split-plot design, plot size and precision of measurement of the effects are not the same for both factors, the assignment of a particular factor to either the main-plot or the subplot is extremely important.

THE DSS MODEL OF THE STUDY

A DSS was built and used based on the previously mentioned field experiment. The field experiment was conducted and the decision was made on it using the conventional procedure. This allowed a baseline on which the DSS of this study bases its judgment regarding the correctness of the procedures demonstrated by the DSS. The DSS consists of three major components. The first one is the database, which was gathered consecutively from the field by the researcher who conducted the field experiment documented in (Abdel-Rahman, 2003). Afterwards, the data is ordered in a matrix format to ease the sequential steps of calculations. The second component is the algorithmic model, which explains the modules of the DSS and shows the general structure of the work as illustrated in Figure (3). The third component is the software that translates the DSS model into a computer-based model that make the last decision about the best seeding rate achievable.

Following the basic idea of the split-plot procedure, the DSS model of this study calculates the analysis of variance (ANOVA) table according to the following steps:

Step 1. Constructing the template of the analysis of variance.

Step 2. Totals and means calculation.

Step 3. The correction factor (C.F.) computation.

Step 4. Creating the main plot analysis totals table.

Step 5. The computation of sums of squares for the main plot analysis.

Step 6. The computation of sums of squares for the subplot analysis.

Step 7. The computation of F-value for each effect that needs to be tested by dividing each mean of square by its corresponding error term.

Step 8. Obtaining the corresponding tabular F-value and check the significance for each effect whose computed F-value is not less than ‘one’ (note: this step is still done manually).

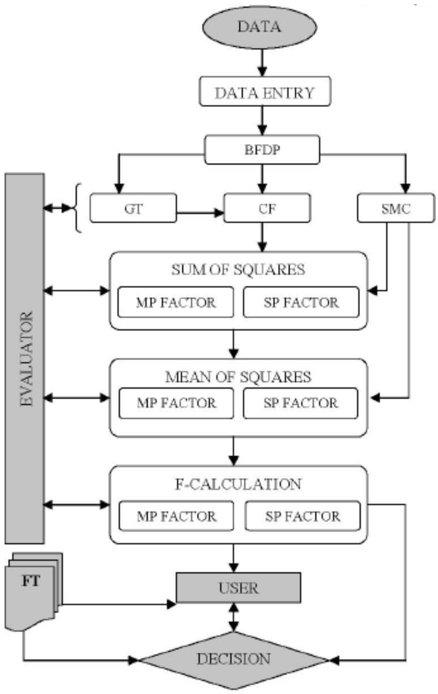

Figure 3 The decision support system model.

According to Figure 3, the final DSS model is a set of subroutines that work interactively, based on the basic assumption of the split-plot algorithm.

The algorithms and their corresponding subroutines (program codes), represented in Figure (3), are explained as follows:

- Data: It is the data that was collected by the researcher from the field (the crop yield).
- Data entry: In this stage, the user will enter the data to the DSS software.
- BFDP: This is an abbreviation for "Before Field-Data Processing". In this module, the number of the treatments is being calculated out of the number of the main plot and subplot factors cases that entered in the previous step.
- GT: this module calculates the grand total, which will be used in the determination of the correction factor.
- CF: here the correction factor is calculated. The FC will be used in the calculation of the square sums and means.
- SMC: This subroutine calculates the vertical and horizontal totals and means of the data matrix.
- SUM OF SQUARES: In this subroutine, the output of the previous subroutine will be squared for the two factors (the main plot and subplot).
- MEAN OF SQUARES: The calculation of means of squares of the field data matrices for the two factors (the main plot and subplot).
- F-CALCULATION: The calculation of the F-value out of the squared means

matrices and error means for the two factors (the main plot and subplot).

- FT: The tabulated value F, used by the user to be compared with the calculated F to determine the last decision.
- EVAUATER: An expert whose revise and check the accuracy of the results in any step (in the case of Sudan, they are the researchers, who are conducting the field experiments).

THE DSS MODEL APPLICATION

The usefulness of this DSS evolves from the its application to the agricultural and environmental research in Sudan. Agriculture is the most important sector in the Sudanese economy. It contributes an annual average of 45 % of the total Gross Domestic Product (GDP) in the last ten years. In addition to its large contribution to the GDP, the agricultural sector employs about 80% of the total labor force including agricultural and related activities (Siddig, 2009). Moreover, it derives activity in the industrial, trade, and service sectors such as transportation, agro-industries, and commerce, which account for a large part of the rest of the economy (Siddig *et al.*, 2009). Accordingly, this DSS tries to serve this orientation. Additionally, the agricultural sector in Sudan suffers a severe scarcity of computer applications (hardware and software). The majority of researchers in these fields lack the capability to use the specialized and advanced software packages related to their work. Therefore, providing such kind of models will setup a base for similar work to be done, and to pull the researcher toward the employment of such computer applications.

Researchers in the agricultural-related sectors require decision support systems that need no previous knowledge and experience in computer software. These systems will help them to achieve perfect, reliable, and accurate results, in a short time and with less effort. Hence, the obtained results and the resulting decision could be a trustful decision. Such a decision support system should help the computer ignorant to apply their work on it, and to assure their very important essential role in the country's economic growth and development.

The third component of the DSS model of the study is the software. It translates the DSS model into a computer-based model to create the last decision. The DSS software is developed using C++ programming language. It determines the best seeding rate depending on the entered data. The software produced by this study computes the coefficients needed by the researcher in a stepwise manner, following the Gomez & Gomez (1984) approach. It describes, and views all the results in a similar way as researchers' manual approach to familiarize it to them (Siddig *et al.*, 2006). . Therefore, this software leads to simplify the whole procedure and reduces the time and effort needed. Moreover, it allows printing the results tables one by one.

FUTURE WORK

Meeting the food production needs in coming decades will require substantial innovation and tools from decision support systems. It should transform the way agricultural research is being conducted in the Sudan. Moreover, research outputs need to affect farmers and consumers directly. Universities, specialized research centers, and computer programmers should study and produce more programs to serve this discipline. Government represented by the Ministry of Science and Technology and universities should plan for a reasonable level of computer software applications and decision support systems in research centers and universities so as to achieve an adequate research that affect the agricultural sector.

This system needs to be expanded to cover more circumstances and variations and to have more flexibility. For instance, additional number of main plot and subplot can be considered. Moreover, this model considers only seeding rate, while other factors affecting agricultural producer need also to be considered in future research.

CONCLUSION

In this paper, a decision support system model of the split plot algorithms was presented. This DSS helps the agronomists to determine the better level of one parameter out of two parameters applied in the field. It applied the algorithms of split plot of Gomez & Gomez (1984) by a decision support system to determine the better seeding rate out of many rates, which is applied in a field to many cultivars in the determined circumstances. The split-plot algorithms of Gomez & Gomez (1984) is always applied when there are two factors under study, and one of them is more important from the researcher point of view. In the case of this study, the important factor will be the seeding rate (sub-plot factor), and the second factor is cultivars (main plot factor). The decision support system was executed by actual field data of more than one experiment and checked by the staff of the Agronomy Department, Faculty of Agriculture, University of Khartoum.

BIOGRAPHY

Dr. Moawia Elfaki Yahia received his B.Sc and M.Sc in computer science from University of Khartoum in 1989, 1995, and his PhD degree in Artificial Intelligence from Putra University, Malaysia in 1999. Currently, he is on leave from University of Khartoum to work as an Associate Professor of computer science at King Faisal University, Saudi Arabia. Dr. Yahia is working as a member of editorial board and reviewer of some journals and as program committee for some refereed conferences in computer science. He is a Member of ACM: Association for Computing Machinery, ACM SIG on Artificial Intelligence, ACM SIG on Knowledge Discovery in Data, International Steering Committee of Arabic Computer Society, and International Rough Sets Society. Dr. Yahia received TWAS award for Young Scientists in Developing Countries in 2006. He published over 25 articles in international journals and proceedings. He is author of two Arabic textbooks: Analysis and Design of Algorithms and Foundation of Database Systems published by Sudan Open University Press. His research interests are: intelligent hybrid systems, data mining, neural networks, rough set theory, and information retrieval.

Dr. Khalid Siddig is an Assistant Professor at the Department of Agricultural Economics of Khartoum University in Sudan. He obtained his B.Sc. in computer Science from the IUA and M.Sc. in computer Science from Alneelain University in Sudan. Moreover is obtained an honors B.Sc. and M.Sc. degrees from the Department of Agricultural Economics of the Khartoum University and a Ph.D. degree from Giessen University in Germany. He accumulated several experiences in teaching and research in computer science and agricultural and development economics during the last ten years. Currently, he is a consultant of the United Nations office of Geneva, Switzerland. During the last ten years, Dr. Siddig has received several awards including

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