Developing a decision support model for choosing appropriate irrigation Systems

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Abstract: Limited water resources and a growing population which brings the need for producing more food have motivated the countries around the world to use water and soil resources cautiously with the goal of increasing their productivities. A good attempt to increase productivity is a well chosen irrigation system which has a high performance with respect to its local conditions. Otherwise it may cause a waste of time and expense at both design and implication phases, especially in cases of pressurized irrigation systems. Expert choice systems which use a data bank to help decision making, are useful tools that can help users to easily solve complicated problems that need a lot of experience and high levels of knowledge to be solved. In this study a model was developed with help of a programming language. The model simplifies the process of choosing an irrigation system. By presenting acceptable results in some sample problems, model's performance was evaluated to be good.

[Alireza Masoudi, Azad Heidari, AbdolMajid Liaghat. **Developing a decision support model for choosing appropriate irrigation Systems.** *World Rural Observ* 2013;5(2):30-35]. ISSN: 1944-6543 (Print); ISSN: 1944-6551 (Online). http://www.sciencepub.net/rural. 6

Key words: Decision support systems, Irrigation system choosing, Pressurized irrigation, Water resources

1. Introduction

Limited water recourses and growing population has lead the countries around the world to increased agricultural productivity per land unit and better use of soil and water recourses by utilizing modern irrigation systems. There has been a great progress at both irrigation sciences and equipment manufacturing technology especially in pressurized irrigation, which has lead to introduction of new irrigation methods with increased efficiency. Irrigation systems are divided into two different categories; gravity and pressurized. Trickle and sprinkler are subcategories of pressurized irrigation systems while border, furrow and basin are subcategories of surface irrigation systems. A well chosen irrigation system should be perfectly compatible with the climate surrounding it and has the highest water use efficiency and lowest possible operating and maintenance costs simultaneously. An improper selection of the method in an irrigation system (especially a pressurized one that need particular equipments), will result in wasting of time and money in designing or implication stages and leads to improper operation and waste of precious water and soil recourses, thus make the whole project uneconomical. Lack of information, non-advanced designs and the variety of irrigation systems (especially sprinkler) at an irrigation project primary observation are the probable reasons that hardens the selection of the method that fits best. An effective way for evaluating and selecting a proper irrigation system is to obtain information on water, weather, soil, cropping pattern and social and cultural terms of the zone, using available databases. Understating the features and limits of irrigation systems on one hand, awareness of the zone's physical characteristics, outcomes plus the environmental, social and economical objectives on the other hand, is a complicated process that must be taken into account thoroughly when choosing an irrigation method. In most of these areas decision support system could come in handy to evaluate different scenarios and facilitate decision making (Torkamani.F et al 2012).

Expert systems are branches of artificial intelligence that process and think like an expert and can act like a human advisor in the design area. Expert systems are programs that imitate behavior of a human expert at a particular field. In order to express opinion, the application uses stored information and continues to ask questions until a solution that matches the answers is found. Many researchers have confirmed that, these systems have a high potential for help making decision on agricultural problems, since they have been established on field based experience. There are two stages for evaluating expert systems; first are the steps that should be taken to ensure the accuracy of the knowledge and information of the encoded language and its compliance with the desired program language structure. The second step is to compare the output results of the model with views of at least one expert. Examples of evaluating expert systems by comparison with expert views are: supplemental irrigation of vegetables and fruit trees by Clark et al

(1992) in Canada and choosing the proper variety of rice by Kiolasery et al (1989) in Srilanka.

1.1. Important factors for selecting an irrigation method

Factors for selecting a proper irrigation method are divided in two different categories, Natural and non-natural. Natural factors include water, weather, soil, land topography and products (cropping pattern), and non-natural include social, cultural, required human recourse, operation and maintenance conditions.

Natural and non-natural factors are as follows:

Region's climate: wind speed an temperature

Land topography: general slope, local slope and natural or non-natural object in the land

Energy providing terms: this represents the height distance between the water source and the field.

Soil characteristics: the most important soil parameters for irrigation method selection which can be measured are infiltration rate and easily available water.

Irrigation water quality: Suspended solids concentration, pH, EC and the concentration of Na, Cl, Br, hco3 (bi carbonate), Fe, Mn, Hydrogen sulfide, dissolved solids, biological matters and bacterias.

Irrigation water quantity: distinguishes the amount of land that can be used for agriculture according to the available water

Type of product: cropping pattern of an irrigation network is chosen according to technical, economical, cultural and natural factors. Plant's age, height and cultivating density are the ones important for irrigation method selection.

Cultural aspects: proper operation and maintenance of a modern irrigation method is depended on social and cultural level of the people, safety factor (the way people deal and accept an irrigation system in a region). Previous experience of usage of the modern systems in a region is a positive point

2. Materials and Methods

14 popular irrigation methods with the help of 10 mentioned Indicators (which are divided into 26 factors) were surveyed, analyzed and ranked. In this part of the paper used methods are introduced and then evaluation method will be described.

2.1. An Introduction to the software

Usually a shell or an expert system programming language will be used for creating expert systems. Also both of them can be used. Database (database and imperative program), user interface and inference engine can be the model's components. Figure 1 shows the method which expert systems use for problem solving. Knowledge and information in the database are in two forms:

a. The effects of minor parameters on selecting the irrigation system,

b. The weight of main parameters on the selection of irrigation system

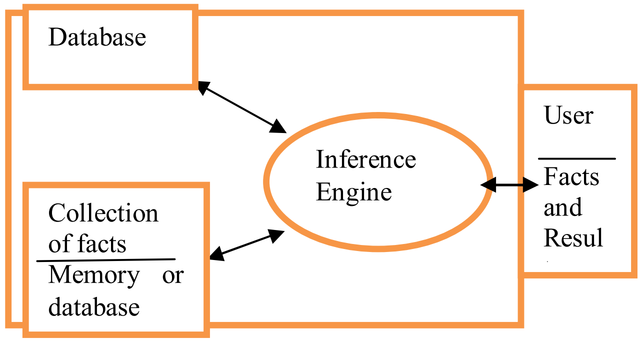

Figure 1: Method of problem solving by expert systems

By minor parameters, we mean classes, limits and components of the main parameters involved in the selection of irrigation system. Impacts degree is a number in the 0-100 range which indicates the success chance of the system under the minor parameters conditions. Zero indicates the certain loose of the system at the conditions (even at the condition of high degrees of minor parameter) and 100 indicates strong success probability for the condition. Specialist's opinions median, forms the weights of the main parameters. Inference engine in expert systems is responsible for inference and implication of the knowledge and information. In order to solve a problem using the model the user must input the conditions to it by using a keyboard. The model is written in the C# programming language. A short description about the language is given in the following.

By emphasizing on the benefits and negligence of some of less used features of the C and C++ languages, the C# which is a modern and object-oriented programming language is designed. A safe and easy to use language was developed for most of the software designers by removing or controlling not understandable or misused cases of the mentioned languages features. For example C and C++ can perform the operation in their memory directly by moving the pointer. The mentioned feature is essential for writing high performance computer software. It can cause many errors (bugs) if such operations are not properly conducted.

Library research and information were used for a better view and comprehend on the irrigation systems and their strength and weaknesses points. Questionnaires were prepared so that according to effective factors in an irrigation systems selection, minor parameters can be rated by experts in a 0-100 range and finally the average number was calculated

2.2. Model Verification and Evaluation

There are two steps: First, Study and verify the given knowledge to the model and the second is Review and evaluate to see if the model's results matches the experts opinions. The first stage is called verification and the second one is called evaluation, and both are described in the following section.

2.2.1. Verification

To ensure that the information is correctly coded and matches the language structure, the verification of the expert system has been done in two ways:

a. The database was divided into several sets of rules

b. Each one of them was examined with the help of the imperative program

For example with the help of the imperative program some of the rules which were related to the water quality and effectiveness degree were applied independent to other sets of rules, then the results were compared with the expected ones; so that the probable errors in entering the knowledge was removed. This work was performed for the other parameters.

2.2.2. Evaluation

In order to evaluate the output results of the model with the expert's opinions questionnaires were prepared. Two experts (E1& E2) were asked to answer the questionnaire, a sample problem including a set of inputs that seem important and critical. The experts according to the problem's condition should rank the 14 irrigation methods in order or by scoring them a number between 0-100. They also were asked to consider another sample problem and solve it similar to the previous one. The criteria for selecting the experts were their records in irrigation (research, managements and implementation fields). Tree problems that were solved by experts (problem one by E1 and two& Tree by E2) are shown in Table 1.

3. Results and discussion

In this section the results of the model and expert's opinions for the tree mentioned problem (table 1) will be discussed.

3.1. Problem 1

Table 1 shows the priority of the irrigation systems selected by the expert and the model. As shown in table 1 result of the model and the expert are in a good agreement, especially till the fifth priority which are options for the economic analysis (final selection). The reason for the difference between the model and the expert's opinion seems to be: 1- There seems to be a socio-economic approach on the parameters impact for selecting irrigation systems and the reason is particular sensitivity on economic and social issues. And preferring semi solid set system to solid set system is probably because of the mentioned reason. 2- The weakness of the model's database regarding the cropping culture. This issue especially occurs in Bubble system cases because in the model's database, using bubble system for row cultivation is unacceptable but in the expert's opinion, a kind of row cultivation is considered that bubble systems in special circumstances can be applied. For this case it is obvious that the model takes a general crop into consideration but the expert comments with respect to the type and value of the plant specifically. If it was not so, there would be no difference between the results.

3.2. Problem 2

Table 3 shows the priority of the chosen irrigation system by expert and the model for the problem 2 conditions (table1). The model's results are shown according to two different kind of weighting, one according to 11experts and other according to only one expert that solved the problem (E2). For this special case the E2 expert believed that using sub-surface system for the current technology in country is not acceptable. So if this choice is omitted, 4 of the first 5 results of the model, matches the results from expert's opinions. Also the economic approach which was mentioned in the problem 1, matters for the solid set system. Another noticeable point in the comparison is the significant difference between the expert's opinion and the model's result in wheel-move priority. The reason obviously is that in the Model's database, applying wheel-move system is not recommended for plants more than 1 meter height (for this problem the plant height was 1.2m) while in the expert's opinion, wheel-move can be used for more heighted plants. This weakness is due to non-phase definition of such condition for the problem and by phase defining conditions it can be solved. It can be concluded that the user should consider the reasoning behind the results, otherwise there can be major errors in the results. Another point is that the results are the same for both of the weighting patterns and this seems to be random because the weighting patterns are considerably different as it will be observed from the third problem.

3.3. Problem 3

The results for the third problem's conditions (table1) are presented in table 4 based on two weighting patterns and the expert's opinion. As mentioned before (problem 2) if the subsurface system is neglected from the comparison of the results, it is observed that the model's results weighted by the expert are better than the weighting for all of the experts view. Even though there seems to be a good fit among different results, if the socio-economic approach was not taken into consideration, the model's results would match the expert's opinion better.

4. Conclusion

As observed in different stages of this research, in Iran selecting the irrigation method seems to be personalized preference, so it is important to regulate it on scientific, experimental and technical basis. Many empirical and qualitative factors affect this problem because of its nature. Expert systems can be applied because they simulate human thinking processes and are able to solve this kind of problems.

As mentioned before, dependence of expert systems to related knowledge and lack of access to some of the parameters (such as plantation, water source quantity, economic analysis, etc) caused shortcomings in the database of the model. It seems that with plan and the basic framework of the present model, solving and completing of the shortcomings seems to be easier than any other approach. In this regard the weighting pattern given by the 11 experts seems to be adequate for the main parameters. The present model could not do the economic analysis and can be used only for preliminary selection. Top five results of the model (along the given recommendations) are appropriate for the final stage (economic evaluation) of irrigation system selection.

Table 1. Problems conditions

Problems conditions			Unit	Problem 1	Problem 2	Problem 3
Soil resources		Land Area	Ha	35	35	35
		Land Shape	-	Regular	Regular	Regular
		Land slope	%	3	3	0.25
		Slope uniformity	-	Fairly uniform	Fairly uniform	Fairly uniform
		Objects in the field	-	None	None	None
		infiltration rate	mm/hr	About 25-40	15	15
		Easily available water	mm	About 60-110	120	120
		Water supply's height from farm	m	35	35	35
		Water table depth	cm	400	400	400
Water Supply	Quantity	Available discharge	lit/s	15	31.5	35
		Delivery type	-	Continuous	Continuous	Continuous
	Quality	Suspended Solids Concentration	mg/lit	110	110	50
		Biological matters	No/ mlit	8000	8000	10000
		EC	µmho/ cm	700	700	2500
		pH	-	7.5	7.5	7.5
		Fe, Mn, Hydrogen sulfide, B (respectively)	mg/lit	0.1, 0.2, 0.1 and 2	0.1, 0.2, 0.1 and 2	0.2, 0.1, 0.2 and 2
		Cl, Na, Bi carbonate (respectively)	mg/lit	80, 60 and 300	80, 60 and 300	80, 60 and 300
Cultivation parameters		Cultivation type	-	Row	Row	Row
		Root depth	m	0.9	1	1
		Crop height	m	1.5	1.2	1
		Crop value	-	Average	Average	Average
Climate		Wind speed	Km/hr	18	18	15
		Pan evaporation	mm/day	8	4	5
		climate	-	Semi arid	Semi arid	Semi arid
		Average annual temperature	°C	20	20	20
Social		Workers skill	-	High	High	High
		Available workers	Man- hr/ ha	>0.5 (low)	0.5 to 1 (average)	0.5 to 1 (average)
		Experience& Cultural aspect	-	Experienced, Positive attitude	Experienced, Positive attitude	Experienced, Positive attitude
Regional sources		Available facilities (equipments or repair shops)	-	Available for all kind of systems	Available for all kind of systems	Available for all kind of systems
Other		Way of supplying water to field	-	Channel	Channel	Channel
		Importance of irrigation during night	-	Average	Average	Average

Table 2. Irrigation systems priorities arranged by model's results and the specialist for problem 1

Priority	Specialist's view	Model's result	Priority	Specialist's view	Model's result
1	Sub surface	drip	8	Border	Gun
2	Drip	Micro jet	9	Hand move	Hand move
3	Micro jet	Sub surface	10	Gun	Border
4	Center pivot	Center pivot	11	Bubble	Basin
5	Linear	Linear	12	Furrow	Furrow
6	Solid set	Solid set	13	Basin	Bubble
7	Semi solid	Semi solid	14	Wheel move	Wheel move

Table 3. Irrigation systems priorities arranged by model and specialists view (in two weights) for problem 2

Priority	Specialist's view	Model's result weighted with mode of all specialists view	Model's result weighted with mode of the specialist's view	Priority	Specialist's view	Model's result weighted with mode of all specialists view	Model's result weighted with mode of the specialists view
1	Drip	Micro jet	drip	8	Gun	Gun	Solid set
2	Solid set	Drip	Sub surface	9	Hand move	Hand move	Hand move
3	Center pivot	Sub surface	Micro jet	10	Border	Border	Border
4	Linear	Center pivot	Center pivot	11	Furrow	Basin	Basin
5	Semi solid	Linear	Linear	12	Basin	Furrow	Furrow
6	Micro jet	Semi solid	Semi solid	13	Bubble	Bubble	Bubble
7	Wheel move	Solid set	Gun	14	Sub surface	Wheel move	Wheel move

Table 4. Irrigation systems priorities arranged by model's results and the specialist (in two weights) for problem 3

Priority	Specialist's view	Model's result weighted with mode of all specialists view	Model's result weighted with mode of the specialist's view	Priority	Specialist's view	Model's result weighted with mode of all specialists view	Model's result weighted with mode of the specialist's view
1	Drip	Micro jet	Wheel move	8	Hand move	Center pivot	Solid set
2	Center pivot	Drip	Drip	9	Gun	Linear	Hand move
3	Solid set	Wheel move	Semi solid	10	Furrow	Gun	Gun
4	Linear	Sub surface	Sub surface	11	Border	Border	Border
5	Wheel move	Semi solid	Micro jet	12	Basin	Furrow	Furrow
6	Semi solid	Hand move	Center pivot	13	Bubble	Basin	Basin
7	Micro jet	Solid set	Linear	14	Sub surface	Bubble	Bubble

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5/30/2013