Development of A Simple Sprinkler System Designing and Pump Selection Expert System (SSSDPS Expert)

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Abstract

In Sri Lanka most of the micro-irrigation systems such as sprinkler irrigation systems are installed with the help of manual based decision making or in many cases without proper designing procedures. These systems do not perform to the expectations. The problems encountered are low water use efficiency due to losses and improper distributions. An expert system with all the design criteria could help non-technical and inexperienced irrigation system installers and farmers. Therefore, this study was done with the objective to develop an expert system for simple sprinkler irrigation system designing and pump selection for efficient water resource use in Sri Lanka. Needed data for the designing, such as crop data, soil data, pump data, pipe data and climatic information were collected from many published reports. Then crop water requirements and irrigation intervals were calculated using standard procedures. Irrigation block selection, lateral pipe selection and main line selection were done through a set of rules and conditional statements. The wxCLIPS was used to represent the knowledge, rules and conditional statements and to develop the Graphical User Interface of the expert system. The developed expert system (Simple Sprinkler System Designing Expert Systems- SSSDPS Expert) can be used easily by interacting with it. The interaction is by just selecting the inputs according to the user's locality and providing simple information through text windows according to the land area. This system generates very accurate outputs and it is shown in the text window. The user can compare many alternate systems through simple interactions with the expert system as it is not taking much time to generate different designs.

Introduction

In Sri Lanka, most of the large-scale farms are commercialized and mechanized to obtain higher crop production and profit. Small scale farmers have started to use advanced technologies in order to maximize the efficiency of available resources. Various agronomic practices such as land preparation, irrigation management, fertilizer application etc., play a major role in achieving the farming objectives. Development of a proper irrigation system is one of the major agronomic practices in increasing the crop productivity. Anyway, manual based decision making is still applied in irrigation system designing and pump selection. It is very difficult to obtain or check variable performances for many possible alternatives with manual decision-making.

Expert system is a branch of AI (Artificial Intelligence) that makes extensive use of specialized knowledge to solve problems at the level of human expert. An expert is a person who has expertise in a certain area. Expert has a knowledge or special skills that is not known or available to most people. "Expert system" is an intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solution. (Feigenbaum, 1982). The knowledge in an expert system may be either the expertise or knowledge, which is generally available from books, magazines, and knowledgeable people. The term expert system, knowledge-based system or knowledge based expert system are often used synonymously.

An Expert system is one of the important application oriented branches of Artificial Intelligence. In the past decade, a great deal of expert systems had been developed and applied to many fields such as office automation, science, medicine, agriculture, etc. At beginning of the development of the agriculture expert systems, the areas selected are applications such as diseases diagnosis, pests of various crops, fertilizer application, crop protection, post harvest technology of fruits and vegetables and irrigation management.

Few Expert Systems are reported for problem solving in the domain of irrigation engineering (Nevo and Amir, 1991; Srinivasan *et al.*, 1991; Mohan and Arumugam, 1995; Linda *et al.*, 1998; Kuo *et al.*, 2000; Silva et al. 2001 and other). Kuo *et al.*, (2000) applied on-farm irrigation scheduling and genetic algorithm to optimize economic profits, simulate water demand, crop yields and area cultivated to each crop according to constraints. Linda *et al.* (1998) developed a decision support system (DSS) for improved irrigation practices, which considers the irrigation management plan prepared by the farmer. Srinivasan *et al.*, (1991) developed an expert system for decision-making on water management in an irrigation project, which determine the type of scheduling based on the computed water requirement, water availability data and general information about the site conditions.

An expert system intended to assist in the diagnosis of centrifugal pump problems (TPUMPX) is recorded (Mario *et al.*, 2004). A number of references were consulted concerning pump application and diagnosis. Individual manufacturers often produce troubleshooting guides for their products. Information acquisition interview process is a summarized excellent form with many checklists and other aids that have been developed to assist the technician. Check lists, and other aids have been summarized in a set of 'flowchart' style blocks similar to decision trees. These were then used to establish rules for the expert system. These were also used to verify the expert system.

The development of a user-friendly expert system for sprinkler system designing and pump selection is much more important in accurate decision-making because no one uses such a system in Sri Lanka for this purpose. By developing an expert system, accurate pump selection, designing a better system layout, etc., could be done according to the user requirement with least efforts in terms of time. Errors could be included when this process is done without an expert so that the expert system will help avoid such problems in pump selection. Development of an exclusive expert system incorporating many variables is a continuous and laborious process. This paper presents the preliminary development of such an expert system. The main objective of this study is to encapsulate specific knowledge on simple sprinkler systems designing and pump selection to a specific expert system.

Methodology

Data Collection

Data needed for a sprinkler system designing and a pump selection process were collected for this study. The data requirement is categorized as crop data, soil data, sprinkler data, pump data, water resources data and details of the cultivated area. Type of crop, root zone depth (m), peak period K_c value and the height (m) are the crop data collected. The soil data collected are; the type of soil, moisture holding capacity of the soil, infiltration rate and texture of the soil. The sprinkler data are; sprinkler type, operating pressure of the sprinkler (bar), application diameter of the sprinkler (m) and flow rate of the sprinkler (m^3/ hr). Water resources data are; the type of water source (pond, river, lake), distance to the water source from the pump or field (m) and the depth of the water source from the field (m). Data on the cropped area are; length of the field (m), width of the field (m), district and evapotranspiration rate (mm/ day). Data needed on the pipe types are; type of the pipe (LDPE, PVC), friction co-efficient of the pipe and the diameter of the pipe (mm). The pump related data are; total dischargeable head (TDH), discharge rate (m^3/hr), required horsepower (m), diameter of the inlet (mm) and diameter of the outlet (mm).

Data Input to the Expert System

Data input to the expert system was done through dialog boxes and input boxes. The dialog boxes allow selection of different choices while input boxes allow the input of data to the system. Crop data, field location (area or district) and location related weather data, type of water source, sprinkler model and type of pipes used were coded into dialog boxes. Input text boxes were created to insert the land width and length, distance of water source from the field and suction head.

Irrigation Water Requirement

Crop water requirement (ET_c) is the product of reference evapotranspiration (ET_o) and crop coefficient (K_c). Peak period K_c is considered for the design purpose as meeting the peak demand will assure water requirements during other periods.

The net irrigation water requirement (NWR) for the field is given by;

$$NWR = (\theta_{fc} - \theta_{pwp}) * RD * MAD \qquad 01$$

where; θ_{fc} is field capacity, θ_{pwp} is permanent wilting point, RD is root depth, and MAD is management allowed deficit. The irrigation interval was calculated by;

$$\text{Irrigation Interval} = \frac{NWR}{ET_C} \qquad 02$$

Irrigated Block or Land Division

Irrigated area or the block was selected according to the user inputs. The system was developed to select irrigated land area according to few conditional statements. If the land area is less than or equal to 0.101 ha, the system automatically takes that area as the irrigation block and the irrigation is done at once. If the land area is between 0.101 ha and 0.405 ha, the land area is divide by 0.101 ha and a new value is assigned as the number of irrigation blocks. If the land area is larger than 0.405 ha, the model sets a condition where the land is divided by irrigation interval and the value is assigned as the irrigation blocks.

Determination of the Laterals

The laterals are assumed to be laid along the width, so that the lateral length will be half the width of the land. Number of sprinklers along a lateral and the total lateral flow was calculated according to the selected sprinkler type considering the sprinkler data. The critical area and critical diameter of the lateral pipe was determined considering the flow velocity as 1.5 m/ s or less.

Friction Loss

Friction loss along the main and lateral lines were calculated using Hazen William's Equation (Eq. 3);

$$h_f = kL\left[\frac{\left(Q/C\right)^{1.852}}{D^{4.87}}\right] \qquad 03$$

Where, h_f is the friction loss as a head (m), k is the conversion constant ($1.22*10^{10}$), L is the pipe length (m), Q is the volume flow rate (l/s), C is the Hazen Williams friction co-efficient and D is the pipe diameter (mm). When the first sprinkler is located at half of the sprinkler spacing, the Christiansen equation (Eq. 4) was used to calculate the F factor.

$$F = \frac{2N}{2N-1}\left\{\frac{1}{m+1} + \frac{\left(m-1\right)^{0.5}}{6N^2}\right\} \qquad 04$$

Where, m is 1.852 for Hazen Williams equation and N is the number of sprinklers.

Pump Requirement

Figure 01 elaborates the head requirement for a pump system. The total dynamic head of the pump can be found using Equation 5.

$$TDH = h_{fix} + h_{var} \qquad 05$$

where; TDH is the Total dynamic head, h_{fix} is the fixed system head, and h_{var} is the variable system head.

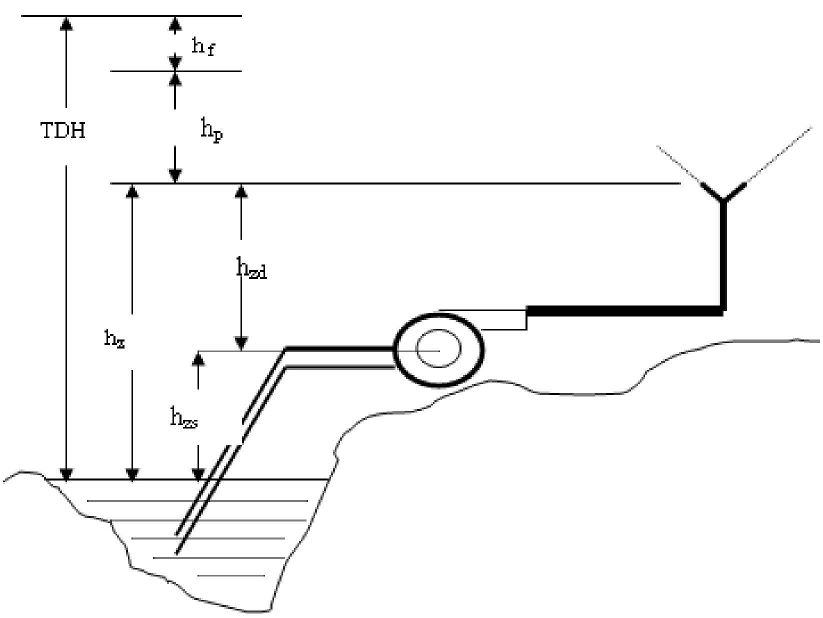

Figure 01: Elevation, pressure and friction head in a centrifugal pump installation

The fixed system head does not vary with the discharge. It is made up of the difference between the static water level and elevation to the discharge point. The fixed system head can be calculated using Equation 6.

$$h_{fix} = h_{zs} + h_{zd} \qquad 06$$

where; h_{fix} is the fixed system head (m), h_{zs} is the static head on the suction side of the pump (m), and h_{zd} is the static head on the discharge side of the pump (m).

In this case, the pressure at the outlet is variable because the sprinkler nozzle is an orifice for which nozzle discharge is a function of the nozzle pressure. So that, variable system head h_{var} (m) can be calculated by using Equation 7.

$$h_{var} = S_{well} + h_f + h_p + (v^2/2g) \qquad 07$$

where; S_{well} is the well drawdown (m), h_f is the total friction head loss in main line and fittings (m), h_p is the pressure heads at critical discharge point in distribution system (m), V is the velocity at critical discharge point in distribution system (m/s), and g is the acceleration due to gravity (m^2/s).

Field Testing

Data were obtained from already installed sprinkler systems in Anuradhapura area and input data were entered in to the expert system for validity checking. Then the system generated data and manually calculated data were compared.

Expert System Development

The expert system building involves several steps, which could be categorized into three major phases. The first phase; the pre-design phase has the planning, research and analysis and conceptual design. The second phase; the design phase is where the user and graphical interfaces, databases, models, and knowledge bases are designed. Incorporating all these components will complete the design phase of the expert system. Interactive problem solving is the interaction between the expert system and its user, allowing more responsive and user centered view of the problem. The user interface is critical, as it allows the user to understand the software and data management used in the expert system. Designing of databases take care the effective management of input and output data. Model management, which is a component of the model base, is an abstraction of reality whose purpose is to help decision maker's focus on the main elements of problem. The third phase; the implementation and adaptation phase where the testing, evaluation, demonstration, maintenance, documentation, and adaptation to respond continuously varying user needs.

Simple Sprinkler System Designing and Pump selection expert system (SSSDPS Expert) was designed using wxCLIPS expert system shell (Smart, 1997). wxCLIPS was developed to enable CLIPS programmers to write portable, graphical programs which run under windows. It is essentially CLIPS modified to work with an event driven style of programming and a set of GUI function.

Result and Discussion

Features of the Developed system

When operating the developed expert system, the Graphical User Interface (GUI) (Figure 02) guides the user through the program. The GUI contains many features such as title bar, menu bar with file, modeling approach and about as sub-menus, execution button, main screen with output display location (text window) and a sub-frame.

Operating the Expert System

The system gets activated and prompts the crop selection dialog box when the start button is pressed (Figure 02). Crop selection dialog box (Figure 03) shows crops available in the data base of the system. User can select a suitable crop for the locality. When selecting a particular crop, the system automatically binds the relevant information of the crop to variables which are used in mathematical modeling within the developed expert system.

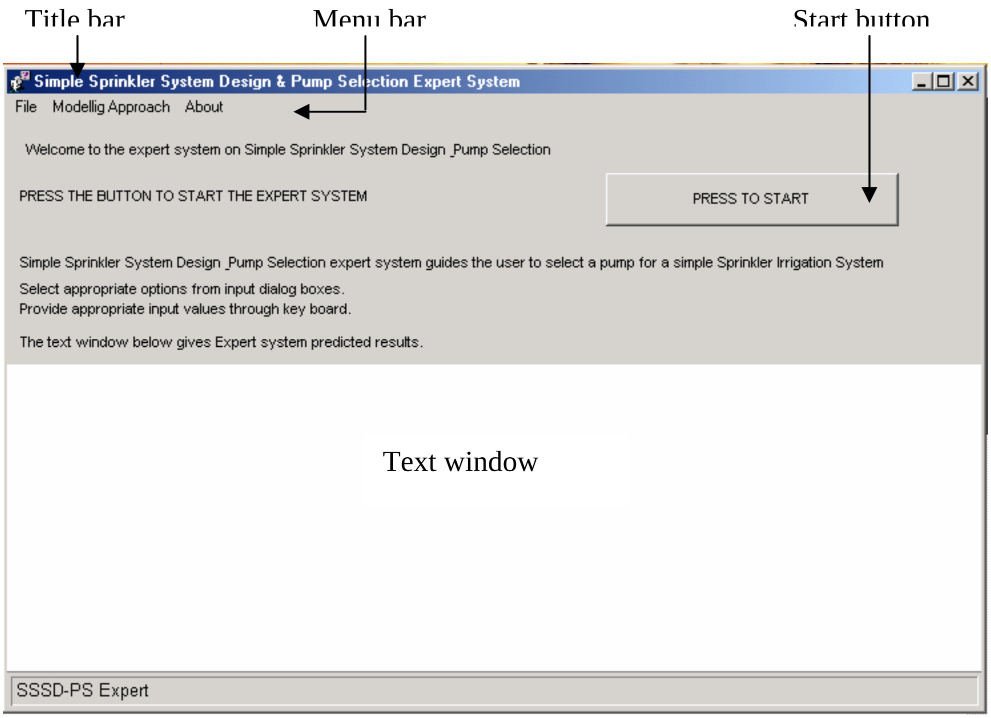

Figure 02: GUI of the designed expert system

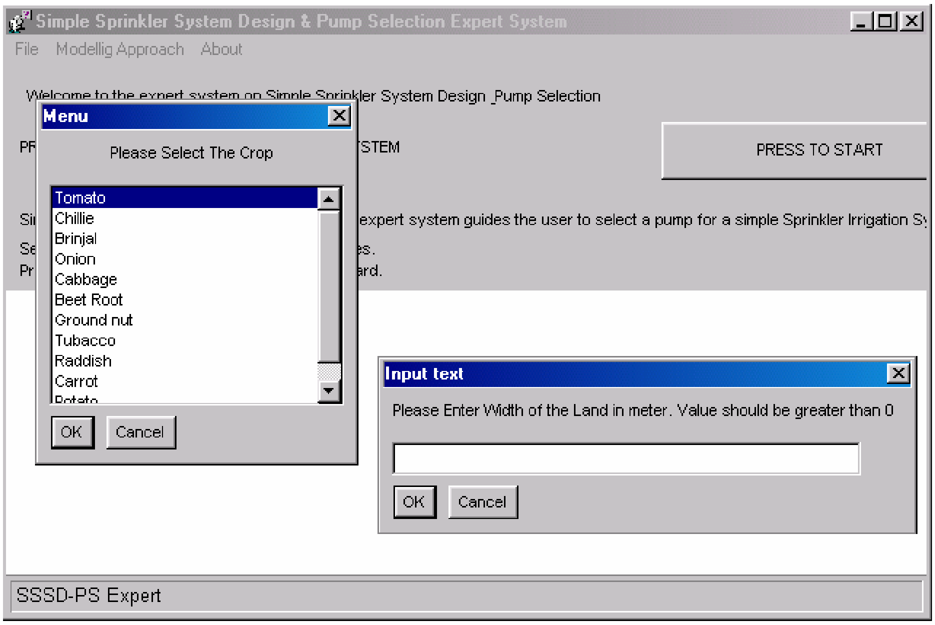

Figure 03: Sample dialog box and an input box

Upon selection of the crop, the system requests the user to select the area/locality through a dialog box. The model binds the climatic conditions of the area and the soil data when the locality is selected. As soils are varying widely, the data base needs to be equipped with enough data on agricultural soils. Land width, land length distance of water pump to field and suction head are entered through input boxes.

With all above information in the system memory, the expert system requests sprinkler information. User is prompted with different option to select a suitable type of sprinkler. When the user selects the type of sprinkler, the system automatically binds the sprinkler specific design information to variables.

After selecting the sprinkler type, the system needs to know the lateral pipe type and then it calculates the lateral size. When selecting a particular lateral type, the system binds pipe related information to variables. The pressure head needed at the critical sprinkler on the last lateral is calculated based on above information gather through user intervention. It also calculates the total volume required for the sprinklers on the lateral.

After selecting the type of the lateral, the system through a similar dialog box, collects the information on the main line type. With information from the database on type of the main line, the friction loss along the main line and the diameter of the main line are calculated. These intermediate values are presented for the user in the output window in order to keep the user informed about the inputs and intermediate values.

System generates the final output of the designed system after entering/selecting all the inputs to the system. The output sheet contains all the given inputs and details of the designed sprinkler system such as sprinkler model data, proposed sprinkler system, proposed irrigation events and pump selection details as shown in Figure 04 allowing the user to get a comprehensive idea about the designed system.

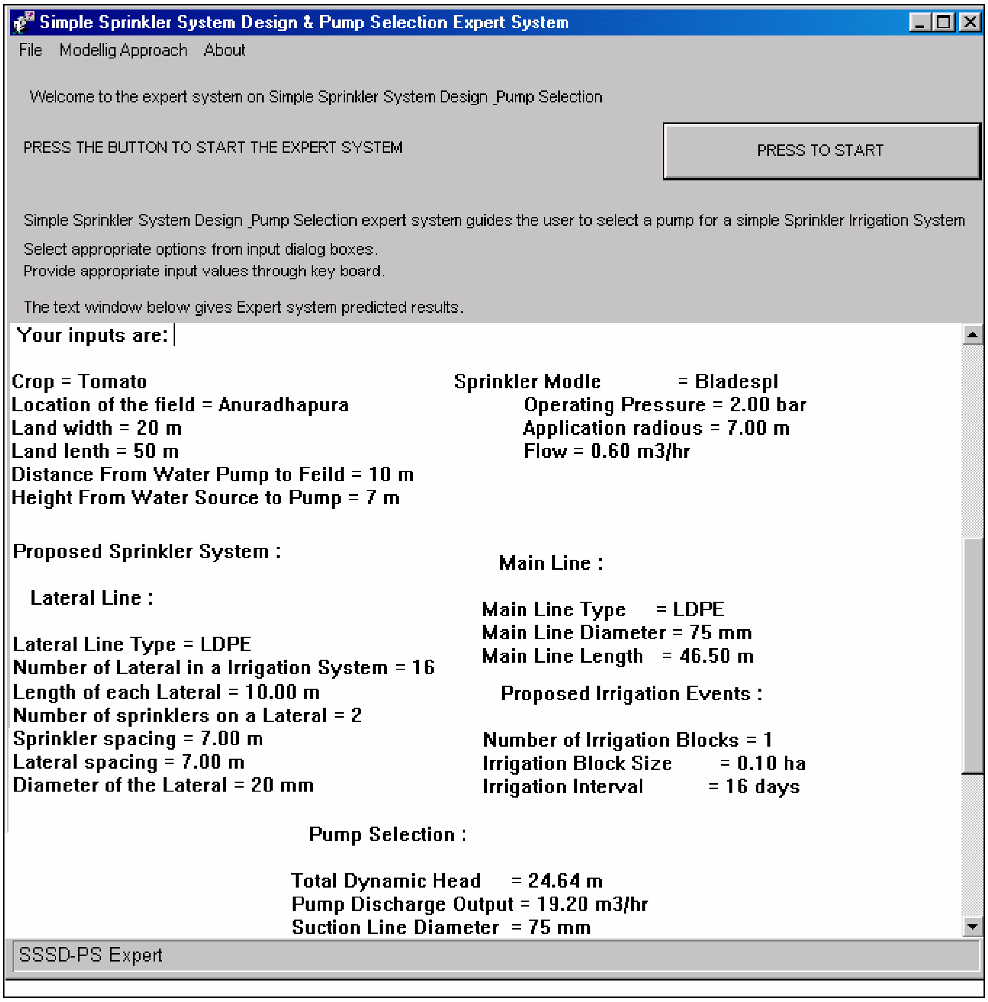

Figure 04: System generated output

Model Validation

When comparing the system generated results and manually calculated values, there are no significant differences between the field test data and the system generated results. However, slight differences on the pump selection can be noted as shown in Table 02. The reasons for this variation could be due to more concentration on the climatic conditions of the cultivated area, soil properties and slope of the land.

The SSSDPS Expert is capable of designing simple sprinkler systems with a good pump selection procedure. The preliminary design of the expert system, though it has many limitations, can be used to design sprinkler systems for a level land. Anyway, incorporation of many more input data to the system and refining other input parameters will help to have good sprinkler system designs and pump selection for different field conditions.

Table 02: System generated results and field test data

Input	System results	Field test data
Crop	Beet root	Beet root
Location of the field	Anuradhapura	Anuradhapura
Land width	40 m	40 m
Land length	50 m	50 m
Distance to water pump to field	4 m	4 m
Suction head	3 m	3 m
Sprinkler model	Bladespl	Bladepl
Proposed sprinkler system		
Laterals		
Lateral line type	LDPE	LDPE
No lateral in system	8	8
Length of each lateral	20 m	20 m
No sprinkler on a lateral	3	3
Sprinkler spacing	7 m	7 m
Lateral spacing	7 m	7 m
Diameter of lateral	25 mm	25 mm
Main line		
Main line type	PVC	PVC
Main line diameter	63 mm	63 mm
Main line length	46.5 m	46 m
Pump selection		
Total dynamic head	20.21 m	20 m
Pump discharge output	14.4 m^3/hr	15 m^3/hr
Suction line diameter	75 mm	75 mm

Limitations of the Designed System

The following are the limitations of the developed expert system.

1) The developed system cannot be applied for designing irrigation system in sloppy lands.

2) This system cannot be used to design the sprinkler system in a land where the shape is irregular.

3) This system cannot be applied for designing the sprinkler irrigation system in a windy area.

4) This system cannot be applied to design the sprinkler irrigation system in an area where the water is limited.

5) This system cannot be used to select a pump for a drip irrigation system.

Conclusions

The problems encountered in sprinkler systems designing and pump selection due to lack of technically qualified personnel has created a need for an expert system for the purpose. This preliminary study focuses mainly on the design of such an expert system using wXCLIPS shell which works under windows environment. The SSSDPS Expert is designed with an interactive GUI where the non-experts and non-technical users can browse through the expert system with much ease through interaction with the computer. Almost all the technical data needed for a preliminary designing of a simple system is embedded to the expert system, so that the user only needs to provide field specific information only.

The developed SSSDPS Expert gives very accurate outputs for given conditions. The system output is useful in proper designing of a simple irrigation system. This system can help non-technical users and sprinkler irrigation system installers in Sri Lanka to come up with better system layouts for productivity maximization with the available resources.

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