USE OF EXPERT SYSTEM IN IRRIGATION PRACTICES

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Abstract: This paper presents how expert systems can be used in irrigation practices. Determination of water requirements and interval of application is part of irrigation practices. Mathematical modeling was used long time ago to build computer programs to calculate the crop water requirements. However, some heurestic experience is needed to apply the calculated water quantity in the field, and to take other practical aspects which cannot be included in the model. Expert systems approoach was found very useful in implementing the model, and in coding the heurestic knowledge.

1- Introduction

This paper presents the usage of expert systems technology in irrigation practices. Expert systems are computer programs that simulate the human experts when they solve a problem. Irrigation practices depend on so many parameters that should be considered in order to make a decsion. In addition to the experience of the experts, they sometimes need to combine their heurestic knowledge with mathematical models that calculates the crop water requirements. Earlier efforts have been exerted in developing such models (Hargreaves,1983), (Wilkerson et al, 1983),(Ritichie, 1985),(Jones et al, 1986). However, irrigation practice is not only calculating crop water requirements but it includes other issues which needs human judgement. Expert system technology can help in two ways: first, the mathematical models can be implemented using expert systems technique with the advantage of explaining to the user how the model calculates a certain quantity , and second, the heuretic, and symbolic knowledge which cannot be mathematically modeled is to be included easily. Examples of such knowledge are:

The validation of the parameters values used as inputs to the model such as soil and water properties. These inputs can be fed to the model either manually or through sensors. In both cases erroneous inputs will lead to erroneous outputs. Heurestic Rules could be added to validate these inputs

The application of the calculated water quantity by the model needs sometimes the interaction of the human expert to determine the irrigation methods to be used when flooding irrigation is considered, and dripers or sprayers locations relative to the tree in case of drip or spray irrigation.

The adjustment of the model results in case of abnormal situation such as unexpected rain, unexpected wind, the unapplicability of the mdel results due to practice constraints and/or when the water is not available in the canals in the dateds determined by the model because of fixed schedule controlled by the Ministry of Irrigation.

The generation of inputs to the model in case that the values of certain properties are unknown and cannot be provided by the user.

The inherited irrigation practices that are not documented and are used by experienced growers to store the fruit on trees and control harvest date.

The paper is divided into four sections. The first section is the introduction. The second section reviews previous expert systems developed for irrigation. The third section describes the expert systems for irrigation developed in the Central Lab. for Agricultural Expert Systems (CLAES). The fourth section is the conclusion.

2- Review of Irrigation Expert System

In the following subsections four expert systems related to agriculture practices are presented. The first two are combining models with rules. The third delas with the trickle filter selection. The fourth system handles the design and evaluation of micri-irrigation system.

2.1.The Barley Management Expert System

The barley management expert system was designed to produce water and fertilizer recommendations to maximize yield (Broner et al, 1992). The heart of the irrigation knowledge base is a decision tree for the irrigation decsion. The system checks to see if irrigation is presently necessary based on current soil moisture deficit and crop growth stage. Current soil moisture deficit is estimated by the feel method and the water balance method. Crop development and the corresponding crop coefficient are calculated using growing degree days. The irrigation knowledge base contains a table that relates crop growth stage to the number of growing degree days. The system calculates the number of growing degree days from daily maximum and minimum temperature and looks up a table to identify each crop growth stage.

2.2. The Irrigation Scheduling Component of CALEX/Cotton

The Irrigation Scheduling Component of CALEX/Cotton is responsible for determining the current level of water stress of the crop and forecasting the dates at which the water stress will be sufficient to require an irrigation (Plant, 1989), (Plant et al, 1992) . This may be done by one or both of two methods: extrapolation of leaf water potential values and the water budget method.

To schedule an irrigation based on leaf water potential, the program attempts to fit a simple straight line empirical model to data. The fit is either based on linear regression if there are more than two data points or on measured average rate change of potential if not. The next irrigation is scheduled to be the time when this line intersects a threshold leaf water potential value that is dependent on the degree-days elapsed since planting.

In the water budget method the program successively adjusts the estimated depletion in the root zone by balancing forecasting daily evapotranspiration, rainfall, and root growth into new soil. When the estimated depletion equals the allowable depletion, an irrigation is scheduled. The value of the allowable depletion is determined from a table based on soil type and elapsed degree-days since planting.

2.3.Trickle Irrigation Filter

Choosing a trickle irrigation filter requires expert knowledge about filter types, filter capacities, quantity and quality of supply water, and the filtration requirements of the irrigation system (Chavez and Sammis,1992). The expert system offers a viable method for aiding the selection of trickle irrigation filters when human experts are not available.

2.4.Expert System for The Hydraulic Design and Evaluation of Micro Irrigation Systems

Expert system for the hydraulic design and evaluation of micro irrigation systems (Bralts, 1993) was devloped and implemented using rules knowledge representation. The evaluation of the proposed design was provided based upon simple statistics and economics as well as hydraulic design criteria. After an evaluation of the design is accomplished, recommendations are made to improve the performance of the system both in terms of uniformity of water application and cost.

3- Irrigation Expert Systems in CLAES

In CLAES, Irrigation expert system is considered within a larger framework which is the crop management. Three expert systems are developed for irrigation of Orange, Cucumber, and Lime. The method used for the first two systems (Orange, and Cucumber) was based on model approach implemented using expert systems techniques. The method used for the third system (Lime) was based completely on heurestic approach. The following subsections describe the three systems.

3.1. Irrigation Scheduling Using Model Approach

Irrigation system can be defined in terms of inputs and outputs. The inputs are the properties of soil, water, and climate of a certan plantation in addition to other factors related to the plantation such as the irrgation method, number of trees, drainage status, and others. The outputs are essentially the water quantity, and the application frequency. The inputs can be classified into two broad categories: static data and dynamic data. The static data include data which do not change in short period while the dynamic data include the changeable data in the field. The static data consist of farm data , soil data , data of water used for irrigation, and climate data. Farm data include the area, number of trees, distance between trees and between rows, used irrigation system, source of irrigation water, and drainage system. The soil data include soil texture, field capacity, and permanent wilting point. The water data include electrical conductivity of irrigation water. The climate data include monthly average of daily temperature, daily relative humidity, daily duration of maximum sunshine hours, actual sunshine hours, and extra terrestrial radiation. On the other hand, dynamic data include status of weeds in the farm.

The irrigation schedule is produced using irrigation model (Hargreaves,1983). This model is based on calculating the potential evapotranspiration (ETp) by the following formula:

$$ETp = 0.0075 * (TC * 1.8 + 32) * (0.097 - 0.00042 * RH) * SQRT(n / N * 100) * Ra$$

where :

TC Average daily temperature in centigrade.

RH Average daily relative humidity in percentage.

n Average daily actual sunshine hours.

N Average daily maximum sunshine hours.

Ra Extra terrestrial radiation.

Then the model considers the soil and calculates soil moisture deficit for each crop, taking into account the individual crop requirement by the following equations which compute the water requierment:

$$LR = ECiw / 1.7$$

$$ETa = ETp * KC$$

$$I = (AW * Ad * Rd) / (ETa * IE)$$

$$WU = ETa * I * DF$$

$$WR = WU * (1 + LR) * CF$$

Where:

ECiw Electrical conductivity of irrigation water.

LR Leaching requirement.

KC Crop Coeffiecnt, it differs according to the crop.

ETa Actual evapotranspiration.

AW Available water in soil, it differs according to soil texture.

I Allowable intervals between two irrigation in days.

Ad Allowable soil moisture depletion below field capacity, it differs according to soil texture.

Rd Rooting depth, it varies according to the age of plant.

IE Irrigation efficiency, it differs according to irrigation method.

DF Depreciation factor, it differs according to irrigation method.

WU Water used.

WR Water requirement.

The pervious irrigation model is used in CLAES by two expert systems: the expert system for Citrus crop management in open field (CITEX) (Salah et al, 1993) and the expert system for Cucumber under plastic tunnel (CUPTEX). The following subsections describe briefly how this model is applied in CITEX and CUPTEX.

3.1.1. Using irrigation model in CITEX

In this system the Citrus crop factor (KC) is used and the age of plant is measured in years. The monthly water requirement is calculated according to the monthly average of daily climate data .Four irrigation systems are considered: flooding, drip, micro sprinkler, and overhead sprinkler. The following example presents the irrigation schedule for a specific case:

Plantation date : 01/01/1978

Area : 1 Feddan

Number of trees : 168

Irrigation System : Drip

Distance between rows : 5 Meters

Distance between trees : 5 Meters

Water Source : River

Soil Texture : Clay

Water Salinity : 0.3 mm/hos

Assuming climate data of Tokh directorate and there exists weeds in the given field, the irrigation schedule for this case is as follow:

Month	Quantity m3/feddan/Irr	Frequency
January	0	0
February	360	1
March	290	1
April	280	2
May	310	2
June	350	2
July	330	2
August	300	2
September	250	2
October	220	2
November	320	1
December	350	1

3.1.2. Using irrigation model in CUPTEX

The model is applied using the crop coefficient of Cucumber, and a table is generated that relates the plant age in weeks to its root depth. equations to calculate the amount of water per unit area under normal condition of tunnel. As we only have the monthly average of daily temperature, this average is used as the weekly average. This approximation caused problems when a week lies in two months and also when there is a great change in climatic data from one month to another mont; this change leads to abrupt change in the water quantity. Therefore, the model was adjusted to overcome these problems. Some heurestic measures were also taken to adjust the water quantity according to the following factors: drainage system, soil salinity, putting an upper limit for leaching requirement, and usage of mulch. The system generates ,in addition to the irrigation schedule, the expected reduction in yield, if any, due to the tunnel condition.

The following example present a specific case for the irrigation schedule for cucumber under plastic tunnel:

Plantation date :	15/2/1995
Area :	540 M^2
Drainage System	good
Soil texture	sand
Water salinity	0.3 mmhos
Soil salinity	0.65 mmhos
field capacity	unknown
perminit wilting point	unknown

The irrigation schedule of the first 10 weeks for this case is as follow:

Week number	Starting date	Water quantity Ltr/540 m^2	Interval (days)
1	15/2/95	1120	2
2	22/2/95	750	1
3	29/2/95	900	1
4	6/3/95	1130	1
5	13/3/95	1300	1
6	20/3/95	1500	1
7	27/3/95	1700	1
8	4/4/95	1920	1
9	11/4/95	2150	1
10	18/4/95	2400	1

3.2. Irrigation Scheduling Using Heurestic Approach

Farmers in the old Nile Valley have traditionally used inherited irrigation practices to control the harvest date, quality, and quantity. Most of these practices are undocumented and varied and have not been put in a form to be used by inexperienced lime growers. Therefore, when the Lime was selected to be the second citrus crop for which an expert system was to be build, we decided to use the irrigation inherited practices of experienced farmers in the irrigation subsystem of the expert system for Lime production (LIMEX). This approach needs less data than the model approach.

The climate data are not used but other parameters related to soil, water, and plantation are considered. Other inputs are also considered such as required harvest date, and type of fasting. LIMEX provides the end user with an irrigation schedule like CITEX and CUPTEX

The main idea of this approach was to acquire a basic set of irrigation schedules from the experienced growers taking into account the following factors: plant age, soil type, water EC, soil calcium carbonate content, and required fasting month. If a plantation data have matched the values of these factors for a certain schedule, the system generates this schedule otherwise some modifications are done on the stored schedule before generation.

To illustrate how the irrigation subsystem of LIMEX works, an example application is provided for a drip irrigation case:

plant age is between 6 and 10 years, Soil Texture : sandy, fasting month : 8

soil calcium carbonate content < 20 %,

water EC < 1.

The basic irrigation schedule is:

Month	Qty (L./tree)	Freq. (times/month)
1	25	15
2	25	20
3	25	30
4	25	30
5	25	30
6	30	30
7	30	30
1/8 -15/8	30	15
9	25	30
10	25	30
11	25	20
12	25	15

If some values of those factors changed according to a specific case, the quantity of irrigation water will be recalculated. For example if we have the following case:

Tree Age : 8 years Soil Texture : sandy fasting month : 8

soil calcium carbonate content = 18 %,

Water EC = 1.4 mmous

Number of Tree : 4000 Motor Power : 50 M3/H

The basic schedule will be adjusted to take into consideration the in crease in water electrical conductivity. It will also consider the number of trees in the orchede ant the motor power to generate a prctical advise which is the number of hours needed for the motor to apply the required quantity.

The output schedule will be as follows :

Month	Quantity Lt./Tree	Motor working hours	Frequency (times/month)
1	27.50	2:12	15
2	27.50	2:12	20
3	27.50	2:12	30
4	27.50	2:12	30
5	27.50	2:12	30
6	33.00	2:38	30
7	33.00	2:38	30
1/8-15/8	33.00	2:38	15
9	27.50	2:12	30
10	27.50	2:12	30
11	27.50	2:12	20
12	27.50	2:12	15

4. Conclusion

The usage of expert systems in irrigation practices was found useful for the following reasons:

Model implementation using expert systems techniques has the advantage of explaining to the user how the irrigation schedule is generated,

Heurestic knowledge can be easily integrated with the model as can be seen in CITEX, and CUPTEX cases, and

Inherited practice can be coded and preserved using expert systems techniques as can be seen in case of LIMEX.

Expert systems that perform other functions such as : selecting irrigation filters, and design and evaluation of irrigation systems, are also useful in the irrigation domain.

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