Mathematical and Computational Applications, Vol. 15, No. 1, pp. 108-116, 2010.

A DESIGN OF AN EXPERT SYSTEM FOR SELECTING PUMPS USED IN AGRICULTURAL IRRIGATION

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Abstract- The economical development of Turkey depends on agriculture so yield in agricultural production has to be increased for improving Turkey's economy. Irrigation is also very important factor to increase yield per unit area. Different kinds of pumps such as centrifugal, submersible and deep well turbines are used according to the system conditions for irrigation of agricultural areas. It is very difficult to find an expert at desired time and desired place for choosing correct pump which are varied in different kinds and models. In this study, this problem was to be tried to solve by designing of an expert system. The choosing of proper pump is very important because of the plant efficiency.

The expert system database was formed by using data obtained from commonly used pumps in Turkey. Flow rate and total manometric head which are important for selecting pump were determined by taking into consideration irrigation area, irrigation methods, water resource, climate, soil properties, crop pattern and well characteristics. The software of expert system was developed for Windows operation system by using Visual Basic Programming Language.

In this expert system, when the programme is operated, the trademark/model of pump having the lowest specific energy consumption is determined to be the most suitable pump for the plant at the end of the programme.

Keywords- Expert systems, Selection of Pumps, Specific Energy Consumption

1. INTRODUCTION

Agriculture is very important for Turkish economy. Therefore, productivity in agricultural production needs to be increased as much as possible. The increase in agricultural production can be achieved by sufficient and timely use of agricultural inputs such as agricultural mechanization, plant protection (pest control) and irrigation. Irrigation is the artificial application of water, which is essential for normal growth of plants and which can not be met through natural methods, to the soil at an appropriate time, in the right amount and with appropriate methods. Turkey's total land area is 78 Mha. Almost one third of this, 28 Mha, can be classified as cultivable land. An area of about 8.5 million ha is economically irrigable under the available technology. In addition, 75 % of the total water consumption is used for irrigation [1]. Different types of pumps are used for irrigation depending on farm conditions. These pumps can be classified as centrifugal pumps, submersible pumps and deep well pumps [2]. Today, selection of the correct pump for the plant (facility) is hard to perform due to various planning factors such as different lands, plant type and irrigation method. Eventually, an inappropriately selected pump either does not meet the needs of the plant or consumes more energy than that which can be afforded.

Because of all these reasons, pump selection for different fields, plant types and irrigation methods is a serious problem. An expert is always needed for a correct selection, so it would be more appropriate to develop an expert system for the efficiency of this task.

The agricultural expert system originated in China in the 1980s, and it transforms the expertise of agriculture to computer program for the purpose of spreading expertise and experience, and mimics the human expert to settle problems in agricultural production, it is an effective tool for disseminating agricultural knowledge and technology in areas short of experts. With the development of computer technology, the expertise has been not only in the area of performance of the character and rule, but also in the area of graphics, images, animation and other multimedia information services and knowledge dissemination. The agricultural expert system has played a positive and important role in guiding agricultural production and improving farmers' quality.

An expert system is defined as ''A program that uses available information, heuristics, and inference to suggest solutions to problems in a particular discipline'' [3]. Mckinion and Lemmon [4] developed an expert system called COMAX (Cotton Management Expert), which could be run in micro-computers. This system provides optimum recommendations for managerial decisions in cotton production.

The CHAMBER expert system, which has a dynamic nature, was developed by Jones, J. [5] for "real time" control of environmental factors for plants and determining errors.

In the past decades, expert systems have been applied to various areas. Subject domains that are supported by experts systems include bioengineering, defence, education, engineering, finance, and medical diagnosis.

Expert System proper cover the domains of pump selection and operation of center pivot systems. Hasbini et al. [6] describe an expert system for this problem. The extremes in pressure (i.e. large transient pressures and negative low pressures) occur due to faulty operational changes and are more possible with the advent of telemetry and central control systems. For a single source irrigation pipe network of Eastern Oregon Farming, a transient pressure model was first used to simulate transient pressures resulting from any operational change. Different operating scenarios of pumps and pivots were analyzed. From the analysis, the principles that minimize the occurrence of extremes in transient pressures were framed. This Expert System was developed as a practical decision aid for operational procedures for unskilled operators.

In this study, an expert system was developed regarding the pumps selection belonging to seven different pump firms. This expert system performs the task of pump selection like an expert. Thus economic decisions can be taken more easily. Moreover, this expert system makes it possible to compare selected pumps that belong to different firms according to their number of stages (pump bowls), engine powers, diameters and lengths of the column pipes and specific energy consumptions. Eventually the most proper pump is advised for the plant.

2. MATERIAL AND METHOD

In order to determine the pumps to be evaluated in the study, meetings were held with pump dealers that have substantial sales in Konya. After these meetings and observations, the technical data of pumps obtained from firms such as ALARKO, ÖZSUHAS, ŞAHİNLER, STANDART, MAS, VANSAN and YERSUSAN were used to establish the database. Data which have an important effect on the selection of pumps such as the size of the irrigated area, land and climatic features, land topography, irrigation method, crop pattern and water source were evaluated and included in the database. The data were taken from the relevant literatures, pump manufacturing firms, and pump catalogues. Table 1 shows per stage data in the optimum operating area of submersible pump models of the firms named ALARKO, ÖZSUHAS and ŞAHİNLER.
Essential parameters such as pump flow rate, total manometric head, water source characteristics (type of the water source, maximum amount of water that could be provided from water source, optimum well capacity, dynamic water level and the diameter of minimum equipment pipe) and the maximum diameter of the pump engine for submersible pumps were taken as important criteria that guide the algorithm. The software of the expert system was developed for Windows operation system by using Visual Basic Programming Language. The flowchart of submersible pump selection is given in Figure 1.

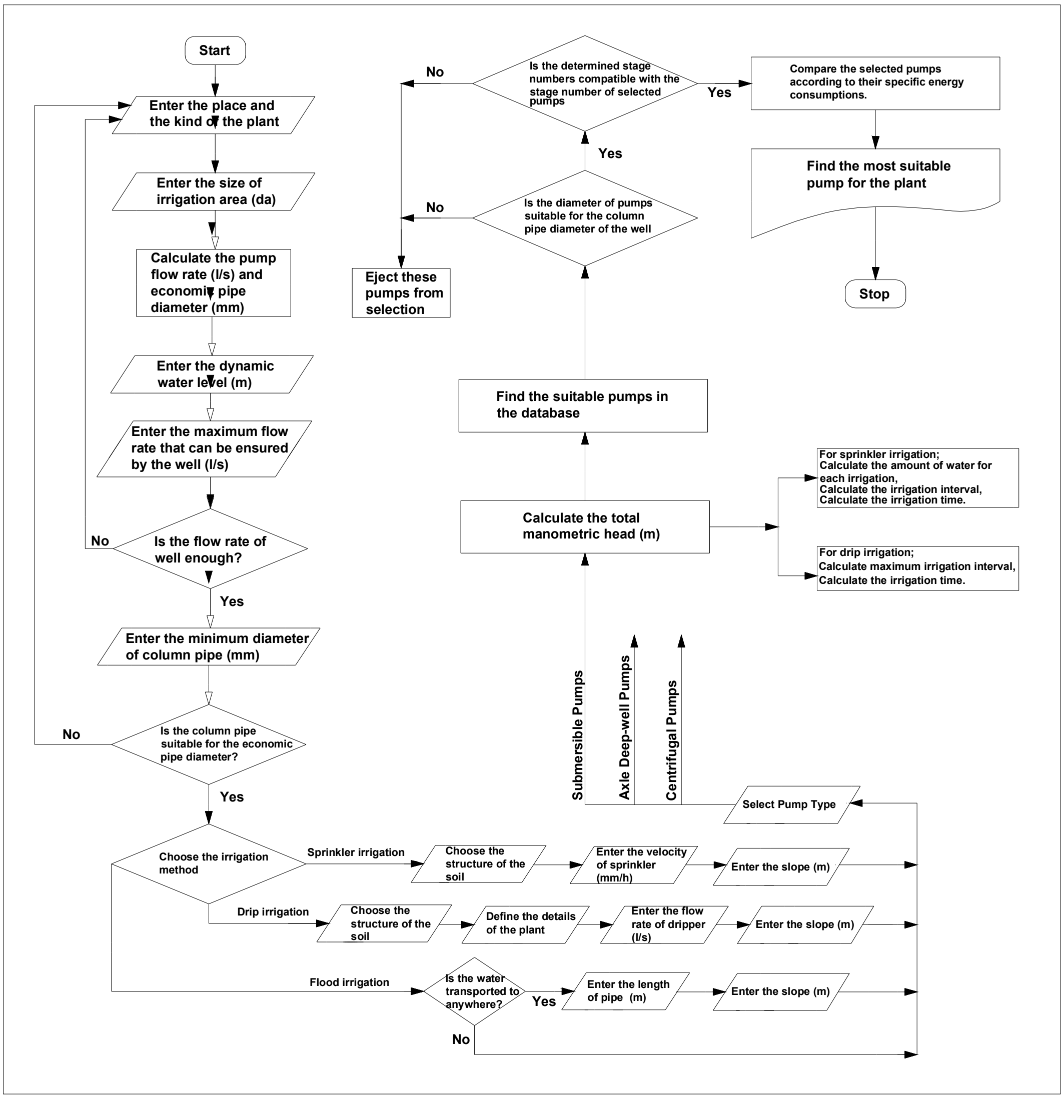

Figure 1. Flowchart of submersible pump selection.

Table 1. Per stage data in optimum operation area of different submersible pump models.

Pump Models	Flow Rate (l/s)	Total Head (m)	Efficiency %	Max. Stage	Pump Models	Flow Rate (l/s)	Total Head (m)	Efficiency %	Max. Stage	Pump Models	Flow Rate (l/s)	Total Head (m)	Efficiency %	Max. Stage
ŞDP 6202 a	1.62	8.125	56	34	ŞDP 6202 b	1.8	7.5	57.5	34	ŞDP 6202 c	1.98	6.5	55.5	34
ŞDP 6203 a	2.88	9.75	65	36	ŞDP 6203 b	3.2	9.125	66.5	36	ŞDP 6203 c	3.52	8.125	65	36
ŞDP 6305 a	4.86	9.77	71	24	ŞDP 6305 b	5.4	9	72	24	ŞDP 6305 c	5.94	8.5	71	24
ŞDP 6306 a	5.94	10	71.5	23	ŞDP 6306 b	6.6	9.25	72	23	ŞDP 6306 c	7.26	8	70.5	23
ŞDP 6308 a	6.88	10	71.8	19	ŞDP 6308 b	7.65	9.5	72.5	19	ŞDP 6308 c	8.41	8.5	72	19
ŞDP 6415 a	13.5	8	67	15	ŞDP 6415 b	15	7.5	68	15	ŞDP 6415 c	16.5	6.5	63	15
ŞDP 8308 a	7.2	22.5	71	17	ŞDP 8308 b	8	21	73	17	ŞDP 8308 c	8.8	19	70.5	17
ŞDP 8412 a	10.35	18.5	69	19	ŞDP 8412 b	11.5	18	71	19	ŞDP 8412 c	12.65	17.5	70	19
ŞDP 8420 a	18.8	16	69	15	ŞDP 8420 b	20.8	15	70	15	ŞDP 8420 c	23.6	13	68	15
ŞDP 8535 a	31.5	17	75	10	ŞDP 8535 b	35	15.5	77	10	ŞDP 8535 c	38.5	13.5	76	10
ŞDP 10650 a	45	37.5	75	8	ŞDP 10650 b	50	33.5	78	8	ŞDP 10650 c	55	24	76	8
ŞDP 10660 a	52.5	25	71.5	6	ŞDP 10660 b	58.3	23	73	6	ŞDP 10660 c	64.11	21	71.5	6
ALDP 6010 a	2.49	8.5	67.5	46	ALDP 6010 b	2.77	7.87	69.8	46	ALDP 6010 c	3.04	7.5	70	46
ALDP 6011 a	2.7	10.8	72	38	ALDP 6011 b	3	10	72.8	38	ALDP 6011 c	3.3	8.75	72.5	38
ALDP 6015 a	3.75	10.41	64	45	ALDP 6015 b	4.16	9.1	67.5	45	ALDP 6015 c	4.576	8.9	66.5	45
ALDP 6020 a	5	10	73	34	ALDP 6020 b	5.55	9.6	73.25	34	ALDP 6020 c	6	8.3	73	34
ALDP 6022 a	5.5	9.21	75	28	ALDP 6022 b	6.11	8.9	74	28	ALDP 6022 c	6.72	8	70	28
ALDP 6024 a	6	10	73.5	23	ALDP 6024 b	6.66	9.5	72.5	23	ALDP 6024 c	7.32	8.6	69	23
ALDP 6031 a	7.75	10.31	64	27	ALDP 6031 b	8.6	10	65.5	27	ALDP 6031 c	9.46	8.92	65	27
ALDP 6045 a	11.25	7.81	66.5	20	ALDP 6045 b	12.5	7.6	67.5	20	ALDP 6045 c	13.75	6.25	68.2	20
ALDP 6055 a	13.68	8.33	71	20	ALDP 6055 b	15.2	8.12	72.3	20	ALDP 6055 c	16.72	7.3	72.4	20
ALDP 8028 a	7	18.75	63	17	ALDP 8028 b	7.77	17.6	63.8	17	ALDP 8028 c	8.47	16.9	64	17
ALDP 8045 a	11.25	15.6	65.5	19	ALDP 8045 b	12.5	14.4	66	19	ALDP 8045 c	13.75	13.6	65	19
ALDP 8048 a	12	16.25	68	19	ALDP 8048 b	13.3	15	68.7	19	ALDP 8048 c	14.6	13.7	68.1	19
ALDP 8075 a	18.8	13.5	71	15	ALDP 8075 b	20.8	12.5	72	15	ALDP 8075 c	22.8	12.5	71.5	15
ALDP 8125 a	31.2	15.75	73	12	ALDP 8125 b	34.7	14.5	74.5	12	ALDP 8125 c	38.17	13.75	74.8	12
ALDP 8131 a	32.75	15	82	11	ALDP 8131 b	36.3	15	82	11	ALDP 8131 c	39.93	13.3	80.5	11
ALDP 10150 a	37.4	28.5	74.5	8	ALDP 10150 b	41.6	25	74	8	ALDP 10150 c	45.5	22.5	71.2	8
ALDP 10200 a	50	25	72.5	6	ALDP 10200 b	55.5	24.1	74	6	ALDP 10200 c	61	23.3	74.5	6
ALDP 14350 a	87.5	29.5	71.7	4	ALDP 14350 b	97.2	20	72	4	ALDP 14350 c	107.4	18.75	68.5	4
ALDP 14500 a	125	42	62	2	ALDP 14500 b	138.8	40	65	2	ALDP 14500 c	152.6	38	65.5	2
ÖS6 Ax a	8	8.96	68.11	22	ÖS6 Ax b	9	8.2	68.15	22	ÖS6 Ax c	10	7.31	66.04	22

ÖS6 B a	10	8.71	60.52	22	ÖS6 B b	11	7.99	61.21	22	ÖS6 B c	12	7.16	60.26	22
ÖS6 C a	10	9.37	58.36	22	ÖS6 C b	11	8.57	58.55	22	ÖS6 C c	12	7.64	57.21	22
ÖS6D a	10	11.13	59.15	20	ÖS6D b	11	10.4	59.89	20	ÖS6D c	12	9.6	59.61	20
ÖS6E a	13	10.86	65	18	ÖS6E b	14.5	10.02	66	18	ÖS6E c	16	9.04	65	18
ÖS7 A a	17	13.64	63.03	17	ÖS7 B b	19	12.51	63.65	17	ÖS7 A c	21	11.16	62.42	17
ÖS8 C a	26	19.42	59.80	15	ÖS8 C b	29	17.9	60.21	15	ÖS8 C c	32	16.12	59.40	15

a: represent value at -5% of optimum flow rate
b: represent value at optimum flow rate
c: represent value at +5% of optimum flow rate

The plant's pump flow rate requirement was calculated by a multiplication of the irrigation module, which is a function of various types of plants being cultivated in the Konya region (climatic and soil properties) and the area of irrigation [7]. Maximum water consumption of plants was taken as a basis in the calculation of the irrigation module.

Dynamic water level, friction losses in the transmission line, velocity head and output pressures according to the irrigation method were used for determination of the system's total manometric head. While sprinkler irrigation systems require an operating pressure between 0.25 and 0.35 MPa, drip irrigation systems require an operating pressure between 0.05 and 0.2 MPa. In the program, output pressures were accepted as 35 m for sprinkle irrigation systems and 20 m for drip irrigation systems [8]. The economic pipe diameter was calculated from the continuity equation according to 2 m/s. On the other hand, Blair equations were used in the calculation of friction losses in transmission line [2].

Before the pump selection, the programme controls the adequacy of the water source capacity (required flow rate) and compares the diameter of the calculated economic pipe with well column pipe. In a negative condition, the user is warned instantly.

Then, the suitable pumps are searched from the database according to required flow rate and total manometric head. After the pump selection belonging to different firms, the features such as number of stages, economic pipe diameters, used pipe lengths, engine powers and specific energy consumptions are calculated.

The number of the pump stage is calculated by the ratio of total manometric head for the plant to per stage head value belonging to the pump model. The constraints of the pump selection in the expert system are related to the database.

The engine power required for the determined pumps were calculated by using the equation given below. Then, calculated pump brake powers were transformed to the standard engine powers.

$$N = \frac{Q.Hm.i}{102.\eta_p}$$

Here;
N = Pump brake power (kW),
Q = Discharge or capacity required for the system (l/s),

Hm = Total manometric head value of each stage belonging to the determined pump (m),
i = The number of calculated stages,
ηp = Pump yield (%)
In submersible pumps, the comparison of standard engine power (N), maximum diameter of pump (Dp) and diameter of the minimum well equipment pipe (Dt) was made according to the following criteria.

$$\textit{if } N \le 30\,kW \textit{ then } Dp \Rightarrow 150\,mm$$
$$\textit{if } 30\,kW < N \le 70 \textit{ then } Dp \Rightarrow 200\,mm$$
$$\textit{if } 70\,kW < N \le 110 \textit{ then } Dp \Rightarrow 250\,mm$$
$$\textit{if } 110\,kW < N \le 133\,kW \textit{ then } Dp \Rightarrow 300\,mm$$
$$\textit{if } N \ge 133\,kW \Rightarrow Dp \Rightarrow 350\,mm \textit{ and } Dt \ge Dp \Rightarrow \textit{Pump is suitable for the well}$$

One of the most important criteria for pump selection is specific energy consumption. Specific energy consumption (kWh/m^3) is a function of the system yield and was calculated by the ratio of pump engine power (kW) to pump capacity (m^3/h).

$$E = \frac{N}{Q\,.\,3{,}6.\eta_t}$$

Here;
E = Specific energy consumption (kWh/m^3)
N = Pump brake power (kW)
ηt = Power transmission system yield (taken to be %85)

3. RESULT AND DISCUSSION

When the programme is operated, standard engine powers of pump or pumps that can meet the demands of the system (flow rate and total manometric head), the number of stages, the diameter and length of the economic pipe and specific energy consumption values can be seen. The trademark/model of pump having the lowest specific energy consumption is determined to be the most suitable pump for the plant at the end of the programme (Figure 2).

Result Of The Program

Trademark and Model	Number of Stages	Economical Pipe Diameter (mm)	Used Pipe Length (m)	Engine Power (kW)	Specific Energy Consumpsion (kWh/m3)
ŞDP6415 a	12	80	65	15	0,459
ÖS6AX b	11	80	65	15	0,424
ALDP6031 b	10	80	65	15	0,480

Figure 2. The result screen of the programme.

In this study, selection of the most suitable pump for an irrigation system has been made. The selection of the correct pump will have a significant effect on the business economics of the plant. The pumps may spend energy that is 10 times their cost in a year [8]. This energy can be reduced to an optimum value by selecting an adequate pump. Today, there is a demand for increasing the plant pumping capacity by about 20 %. A good system design, selection of a high capacity pump, proper maintenance and management are required for operating the irrigation system at high capacity [9].

4. CONCLUSIONS

Expert systems can be an alternative choice for the private sector due to difficulties encountered in finding the expert person at all times and everywhere and high costs of expert persons. Computer programmes known as expert systems are believed to be the best fitting method for the solution of complex problems like pump selection [10].
In this study following suggestions can be made;

- Selection of the pump according to the lowest specific energy consumption will ensure using energy economically.
- Better economic decisions will be taken within a short time.
- Likelihood of making mistakes will be eliminated by the use of the programme and thus damages that will be caused by mistakes will be prevented.
- With the development of this programme, selection of such properties of pumps as cables, electrical organs etc. will be possible.
- This expert system will help pump dealers in selecting the suitable pump from among pump brands with different technical properties.
- The database of this programme can be expanded by entering the technical properties of pumps from different firms.

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