UTILIZING EXPERT SYSTEM FOR COMPREHENSIVE MANAGEMENT OF SALINE SODIC CLAY SOILS

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ABSTRACT

In Egypt, heavy clay soils represent approximately 260,000 feddans of the delta. At present heavy clay areas are either of poor or of low quality mainly due to occurrence and development of salinity and sodicity problems, which hinder realization of the fruitful results of any agricultural inputs. Tina Plain Area of North Sinai is representing the first region of El-Salam canal that located along the Eastern bank of the Suez Canal. It is one of the three regions of the reclamation areas under the El-Salam canal project. The problematic saline sodic heavy clay soil is located at the north-western part of Tina Plain area. The management of problematic heavy clay areas is a multi-disciplinary strategy and joint efforts between key persons who involved in this process. Therefore, great prospects for application and great economic values are promised to adopt Knowledge-Based Expert System (ES) as a management tool in accordance with the research results achieved by the problematic heavy clay soil ameliorating experts and their successful experiences. A user-friendly knowledge-based expert system computer program was developed for management of problematic heavy clay soils. Utilizing of Heavy Clay Management Expert System (HCMEXS) in a saline sodic heavy clay soil experimental field in Tina Plain Area improved the consistency, completeness and correctness of the expert system in compatible with the knowledge of the experts. The recommended strategy of the expert system succeeded to decrease the soil salinity to about 50% within 6 months. It was found that HCMEXS can help users to make appropriate decisions on comprehensive heavy clay management so that the goal of improving heavy clay soil can be achieved; it also helps farmers and stakeholders to make correct decisions on sustainable agricultural practices.

Keywords: Expert system, Heavy clay soils, Knowledge acquisition, Management

INTRODUCTION

Abu El-Azz [1] indicated that, the total Egyptian agricultural land is about 8.0 million feddans (1 feddan = 0.42 hectare) that are almost entirely depended on irrigation. The Delta of the Nile is one of the most fertile and intensively cultivated regions in the world. The DRI [2] concluded that the heavy clay soils represent approximately

260,000 feddans of the delta. FAO [3] mentioned that, the saline and sodic problems are in many instances associated with heavy clay soils. In Egypt, to face the increasing demands for food production, increased attention has been given to reclaim, improve and manage heavy clay soils to solve problems of saline and sodic for optimal crop production.

Rycroft & Amer [4] mentioned that, the risk of soil salinization is particularly acute in clay soils, because there is no economical viable method of draining them and of controlling salinity. Therefore, there is an urgent need to establish the limits for sustainable farming on heavy clay soils and to devise economical types of drainage systems. It was obvious that the drainage management for problematic heavy clay soils is a multi-disciplinary process concern crop variety, water management, soil improvement, drainage management and socio-economic aspects. Hence, the management of problematic heavy clay areas should be a multi-disciplinary strategy and joint efforts between key persons who involved in this process.

Therefore, it was necessary to develop a comprehensive multidisciplinary strategy for management of problematic heavy clay soils and develop a tool to transfer it to the general public of farms and the responsible persons in the field scale. Under such conditions, a Heavy Clay Management Expert System (HCMEXS) was developed to help users to make appropriate decisions on the management of heavy clay soils so that the goal of improving heavy clay soil can be achieved.

The main objective of this study is to utilize HCMEXS in an experimental field of saline sodic heavy clay soils in Tina Plain Area of North Sinai in Egypt. The experimental field has an actual area of 60 feddans. The main characteristics of this field are the heavy clay texture of its soil, poor drainage, shallow ground water tables and the presence of about 30 cm of salt layer on the surface.

HEAVY CLAY MANAGEMENT EXPERT SYSTEM (HCMEXS)

Fontane [5] stated that, the management of water resources is becoming increasingly complex. Emerging computer based decision support systems, and technologies such as expert systems, geographical information system, and decision analysis methodologies are being used to enhance decision-making in this complex environment. The task of building an expert system involves: information gathering, domain familiarization, analysis, design, and implementation efforts. Rafea & Shaalan [6] mentioned that, the adapted methodology of knowledge engineering includes three main activities to produce successive versions of expert system. These activities are:

- Knowledge acquisition,
- Knowledge analysis & modelling, and
- Knowledge verification and validation.

Knowledge Acquisition is considered the bottleneck of the expert system building and probably the most important task in the development of an expert system. Traditionally, human experts have been the source of knowledge for expert systems. Drainage and Reclamation and Improvement experts in Egypt were contributed in this study. Sallam [7] mentioned that the expertise of the experts were collected through a questionnaire that provides knowledge for the different factors that affect the drainage management of problematic heavy clay soils. The collected expertise was form the database of the expert system.

Sallam [7] indicated that the acquired data was analyzed according to Knowledge Acquisition Development System (KADS) approach to get the required database for the expert system and define the main concepts and properties of the system. The documented knowledge was analyzed aiming at identifying relations. The relations are either relations between concepts or relation between expressions. The Expert System HCMEXS was implemented using SICStus Objects and KROL programming language. The Heavy Clay Management Expert System (HCMEXS) is divided into eight subsystems: irrigation system performance; crop management; soil improvement; levelling; sub-soiling; gypsum application; drainage and economic. The main screen of the developed expert system is shown in Figure 1.

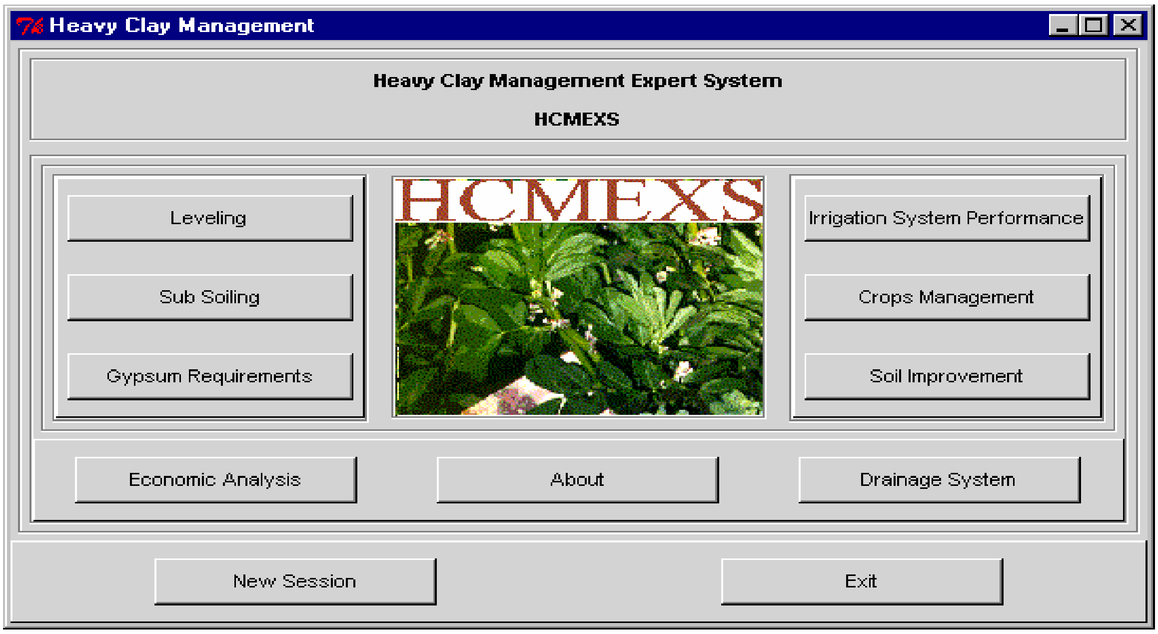

Figure 1: The Main Screen of HCMEXS

Sallam [7] also mentioned that, the developed expert system was validated using the case testing validation technique. This technique aims at testing the developed expert system and finding the discrepancies between expected behaviors of the system according to the knowledge of the experts against the actual behavior. HCMEXS was tested with two typical cases. The results of validation of the system proved the consistency, completeness and correctness of the software in compatible with the acquired knowledge of the experts.

STUDY AREA

HCMEXS was utilized in an experimental field with an area of 60 feddans of saline sodic heavy clay soils in Tina Plain area of North Sinai. Tina Plain area represents the first region of El-Salam canal that located along the Eastern bank of the Suez Canal. It is one of the three regions that will be reclaimed under the El-Salam canal project and it covers about 50,000 feddans. DRI [8] indicated that, the soil texture in the area varies from sand to clay, the heavy clay soil area is only located at the north-western part of Tina Plain area as shown in Figure 2.

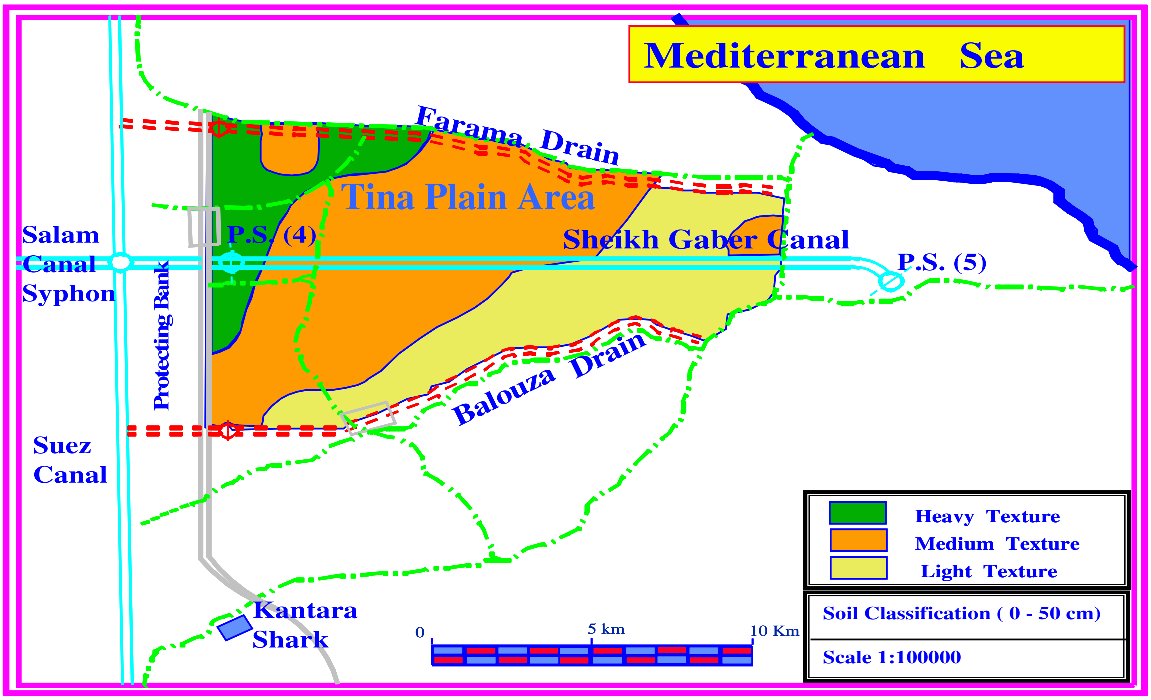

Figure 2: Soil Classification of Tina Plain Area (DRI, 1997)

INITIAL CHARACTERISTICS OF THE STUDY AREA

The experimental area was divided into 4 units (A, B, C, and D) and different soil and ground water characteristics were measured at different investigation points for each unit as shown in Figure 3. The soil classification indicated that the average clay percentage is 56.43% so it represents the heavy clay soils in Tina Plain area. The results of the initial chemical analysis are presented in Table 1. The results indicated that the soil salinity varies between 360 and 550 dS/m with an average of 413 dS/m for the surface layer of the soil (0-50 cm) and varies between 260 and 330 dS/m with an average of 276 dS/m for the other layers (50-150 cm). The prevailing salts are sodium chloride, sodium sulfate and magnesium sulfate. The Sodium Adsorption Ratio (SAR) varies from 50 to more than 100. The value of (pH) for all soils ranged from 6 to 7.8. Therefore, the soil could be classified as saline sodic heavy clay soils. It was also found that the surface ground water salinity varies from 96.95 to 143 dS/m in the majority of the area. The hydraulic conductivity of the soil was measured for different investigation points. It reached in average 0.2 m/day. However, it is not representing the real value for the area as a heavy clay soil where the hydraulic conductivity for this soil is less than 0.1 m/day. This may be attributed to the presence of the surface salt layer.

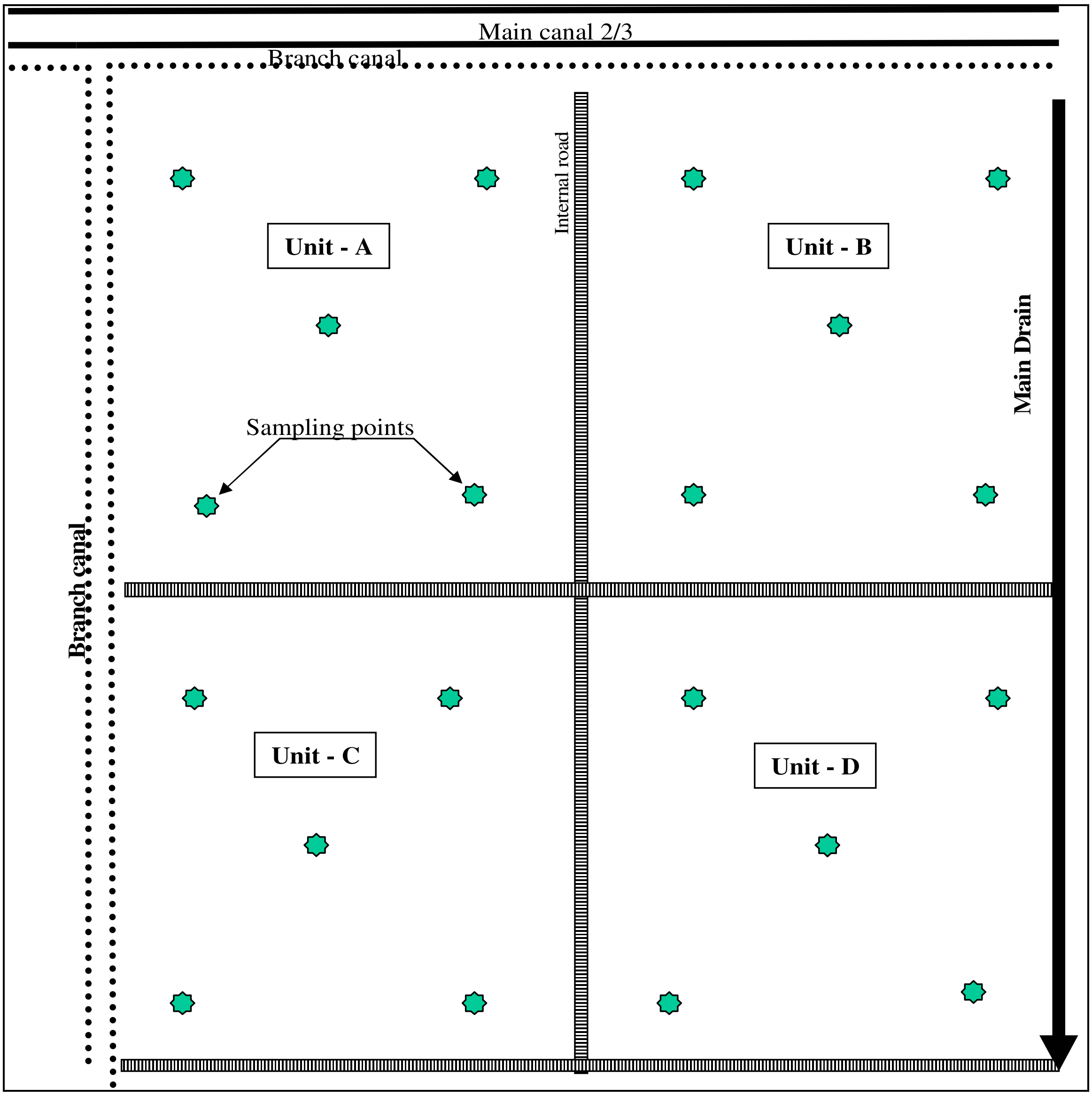

Figure 3: Layout of the Experimental Field

Table 1: Initial Soil Chemical Analysis Results

Unit No.	Soil depth (cm)	Cations (meq/l)				Anions (meq/l)				pH	EC	SAR	Ground Water Salinity (dS/m)
		Na	K	Mg	Ca	CL	SO4	HCO3	CO3		(dS/m)		
A	0-50	2110	0.93	745.00	834.00	2294.00	1391.22	4.62	0	6.82	362.00	75.09	96.95
	50-100	3320	0.97	947.40	1056.80	3108.00	2212.64	4.54	0	6.96	514.00	104.88	
	100-150	1578	0.95	668.75	753.75	1702.50	1276.15	4.30	0	7.03	262.50	59.15	
	150-200	1378	0.93	620.25	724.75	1507.50	1211.38	4.55	0	7.05	252.50	53.12	
Average		***2096***	***0.94***	***745***	***842***	***2153***	***1523***	***5***	***0***	***7***	***348***	***73***	***97***
B	0-50	3350	0.95	1158.67	991.33	3385.00	2111.60	4.33	0	6.72	528.33	102.17	124
	50-100	1673	0.93	700.83	647.33	1790.00	1227.65	4.43	0	7.05	291.67	64.77	
	100-150	1560	0.93	629.50	595.83	1683.33	1098.37	4.53	0	7.10	263.33	67.66	
	150-200	1405	0.95	607.67	629.00	1540.00	1158.67	4.57	0	7.22	251.67	57.07	
Average		***1997***	***0.94***	***774***	***716***	***2100***	***1399***	***4***	***0***	***7***	***334***	***73***	***124***
C	0-50	3233.33	0.95	883.00	1090.33	3361.67	1841.55	4.40	0	7.3	511	97.15	139
	50-100	2890	0.94	875.00	1097.00	1532.00	3324.26	4.52	0	7.2	466	86.24	
	100-150	2825	0.93	858.17	1021.83	3066.67	1568.08	4.50	0	7.2	461	85.52	
	150-200	1450	0.94	423.50	574.83	1536.67	908.10	4.48	0	7.02	230.67	65.85	
Average		***2600***	***0.94***	***760***	***946***	***2374***	***1910***	***4***	***0***	***7***	***417***	***84***	***139***
D	0-50	5145	0.94	977.33	1169.17	5531.67	1754.77	4.45	0	7.13	556.67	147.03	143
	50-100	2956.67	0.94	662.17	859.50	3030.00	1444.70	4.47	0	7.15	440.33	97.65	
	100-150	1706.67	0.95	465.83	592.50	1800.00	961.28	4.65	0	7.07	268.50	73.97	
	150-200	2855	0.94	684.50	900.17	2963.33	1472.77	4.47	0	7.08	439.00	92.30	
Average		***3166***	***0.94***	***697***	***880***	***3331***	***1408***	***5***	***0***	***7***	***426***	***103***	***143***

UTILIZING OF HCMEXS

HCMEXS was utilized in the experimental field where water from the El-Salam canal is available in the secondary and tertiary irrigation system which has been installed. Moreover, main surface drains are available and major temporary drainage pumps are pumping water from the main drain. Detailed inputs data related to soil, irrigation water and ground water of the experimental field for HCMEXS are listed in Table 2.

Table 2: Inputs Data for HCMEXS

Inputs	Value
ECe (*Soil Salinity, dS/m*)	380
SARs (*Sodium Adsorption Ratio of soil*)	83
K (*Hydraulic Conductivity, m/day*)	0.1
CEC (*Cation Exchange Capacity, meq/100g of soil*)	45
θ_{fc} (*volumetric soil water content at the field capacity*)	0.45
SARiw (*Sodium Adsorption Ratio of irrigation water*)	5
ECiw (*Salinity of irrigation water, dS/m*)	1.5
WTD (*Water Table Depth, m*)	0.1
ECgw (*Salinity of ground water, dS/m*)	125

The HCMEXS was run for the inputs data of the experimental field. The results of the expert system proved the consistency, completeness and correctness of the software in compatible with the acquired knowledge of the experts. The recommended strategy for this stage of reclamation in the experimental field was to apply intermittent leaching with surface irrigation and surface drainage (Figure 4). Due to the availability of the irrigation water in the experimental field all over the year from the El-Salam canal, the output of the expert system was including one recommended operation of periodical maintenance of irrigation network (Figure 5). The recommended type of field drains was surface drains with space of 10 m and depth of 100 cm (Figure 6) as a result of the low hydraulic conductivity of the soil (0.1m/d) and the high value of SAR (83). For applying leaching process the required network of surface irrigation canals and surface field drains were constructed in the area.

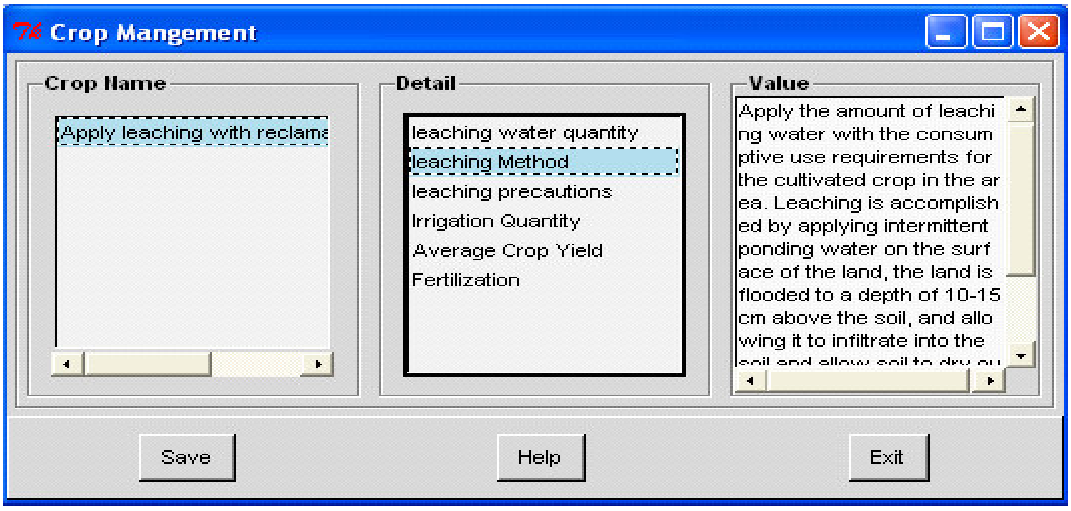

Figure 4: Output screen for soil improvement subsystem

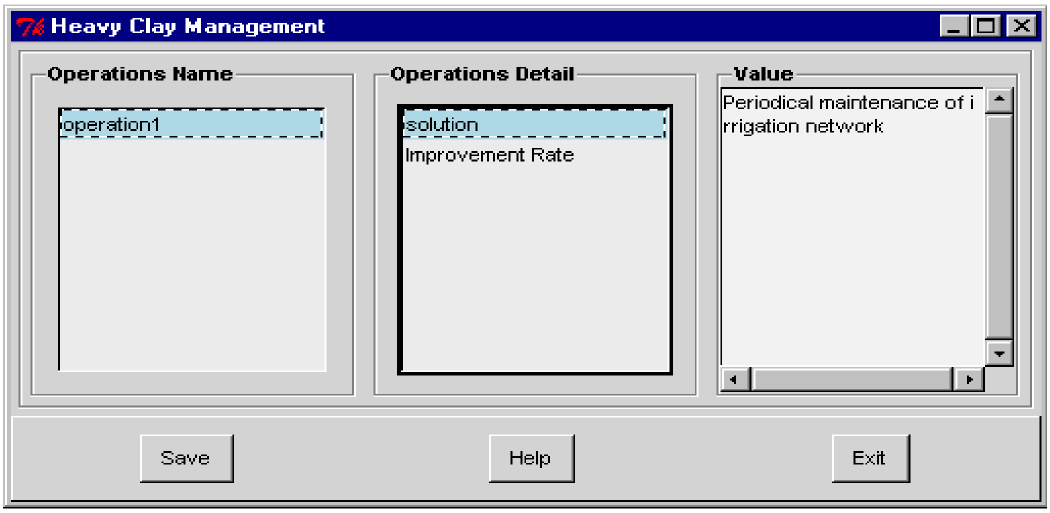

Figure 5: Output screen of irrigation system performance subsystem

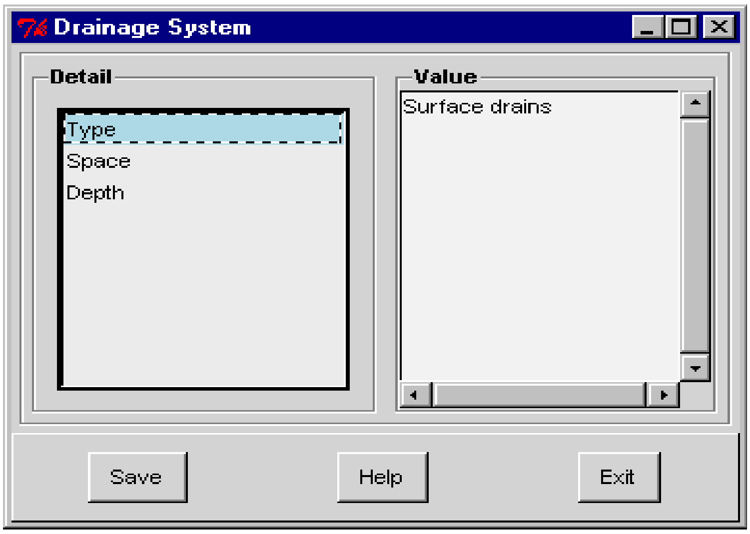

Figure 6: Output screen of drainage subsystem

EVALUATION OF UTILIZING HCMEXS

The recommended strategy of HCMEXS proved success to remove the accumulated salt layer at the soil surface and decrease the soil salinity to about 50% within 6 months of leaching. Data in Table 3 shows that the soil salinity before leaching was ranged from 360 dS/m to 550 dS/m with an average of 413 dS/m for the surface soil layer (0-50 cm) and ranged between 260-330 dS/m with an average of 276 dS/m for the other layers (50-150 cm). Leaching decreased the soil salinity of the surface soil layer and the other layers to about 135 dS/m and 160 dS/m respectively (Figures 7, 8, 9 and 10). Therefore, it is expected to complete leaching process within one year from the beginning. During this stage some salt tolerant crops could be cultivated.

Table 3: Soil Salinity during Leaching Process (dS/m)

Leaching Time	**Initial Soil Salinity (dS/m)**					**Soil salinity after 30 days (dS/m)**				
Depth	**A**	**B**	**C**	**D**	**Average**	**A**	**B**	**C**	**D**	**Average**
0-25	362.0	372.0	363.2	556.7	413.5	229.8	237.8	229.8	214.6	228.0
25-50	362.0	372.0	363.2	556.7	413.5	202.8	184.5	235.0	163.7	196.5
50-75	330.0	291.7	257.5	286.4	291.4	165.4	141.6	112.0	192.8	153.0
75-100	330.0	291.7	257.5	286.4	291.4	165.4	177.6	136.2	153.5	158.2
100-125	262.5	263.3	253.2	268.5	261.9	175.8	176.1	164.8	163.8	170.1
125-150	262.5	263.3	253.2	268.5	261.9	175.8	------	168.6	------	172.2
Average	**318.2**	**309.0**	**291.3**	**370.5**	***322.2***	**185.8**	**183.5**	**174.4**	**177.7**	***180.4***

Leaching Time	**Soil salinity after 60 days (dS/m)**					**Soil salinity after 90 days (dS/m)**			
Depth	**A**	**B**	**C**	**D**	**Average**	**A**	**B**	**D**	**Average**
0-25	233.0	232.75	221.8	238	231.4	221.2	233.2	224	226.1
25-50	225.4	176	214.8	186.8	200.7	169.6	173.4	204.94	182.6
50-75	194.4	178.6	204.2	207	196.1	163.2	185.4	200.8	183.1
75-100	200.2	170.8	182.6	193.2	186.7	170.8	162.3	182.62	171.9
100-125	196.0	174	212.2	181.4	190.9	192.8	191.42	184.22	189.5
125-150	208.6	146.4	199.4	208	190.6	168.8	201.92	179.2	183.3
Average	**209.6**	**179.8**	**205.8**	**202.4**	***199.4***	**181.1**	**191.3**	**196.0**	***189.4***

Leaching Time	**Soil salinity after 120 days (dS/m)**					**Soil salinity after 150 days (dS/m)**			**Soil salinity after 180 days (dS/m)**		
Depth	**A**	**B**	**C**	**D**	**Average**	**A**	**C**	**Average**	**A**	**C**	**Average**
0-25	219.8	202.6	225.6	222.0	217.5	128.2	112.8	120.5	112.4	157.8	135.1
25-50	178.0	175.6	190.6	167.8	178.0	142.4	135.2	138.8	129.8	146.0	137.9
50-75	174.2	173.6	162.8	157.0	166.9	172.6	156.6	164.6	150.0	161.3	155.6
75-100	186.4	206.8	177.6	171.4	185.6	182.6	168.6	175.6	184.0	166.2	175.1
100-125	187.8	161.6	190.5	136.0	169.0	164.8	155.5	160.1	171.8	137.2	154.5
125-150	182.2	------	171.3	------	176.7	143.6	151.4	147.5	------	------	------
Average	**188.1**	**184.0**	**186.4**	**170.8**	***182.3***	**155.7**	**146.7**	***151.2***	**149.6**	**153.7**	***151.6***

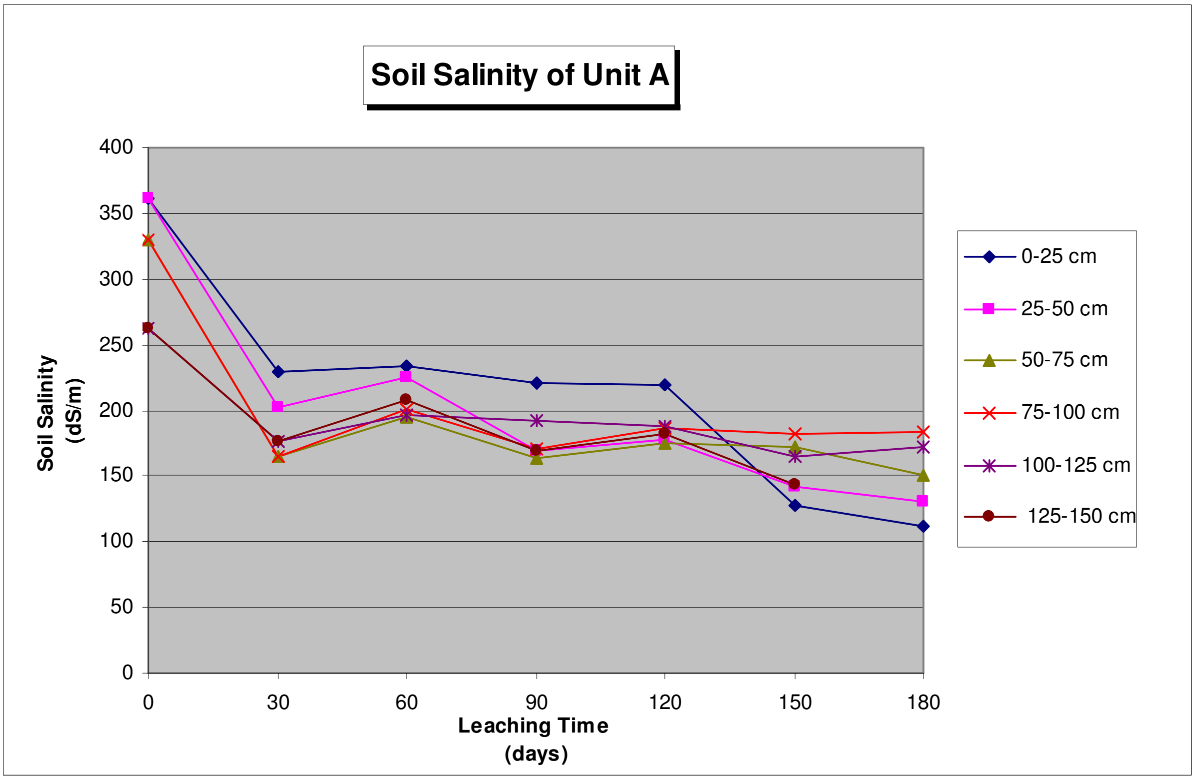

Figure 7: Impact of Leaching Process on Soil Salinity of Unit A

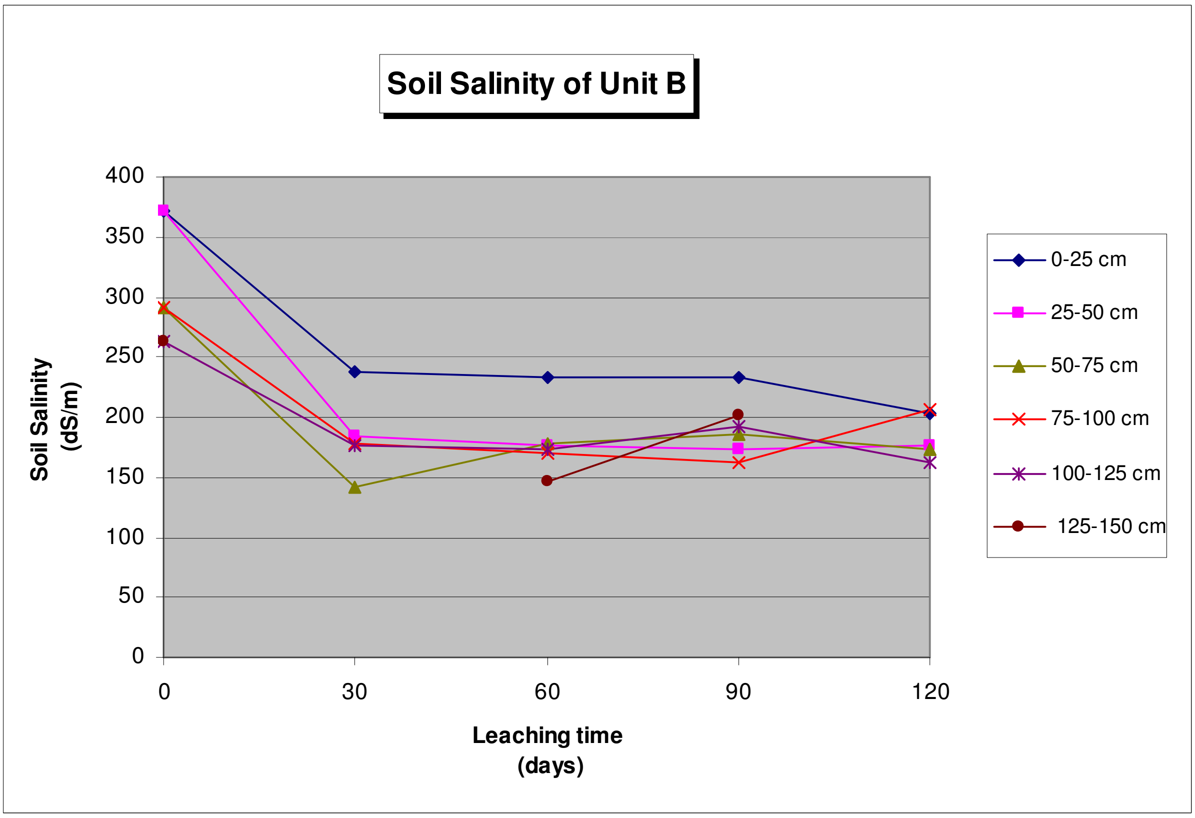

Figure 8: Impact of Leaching Process on Soil Salinity of Unit B

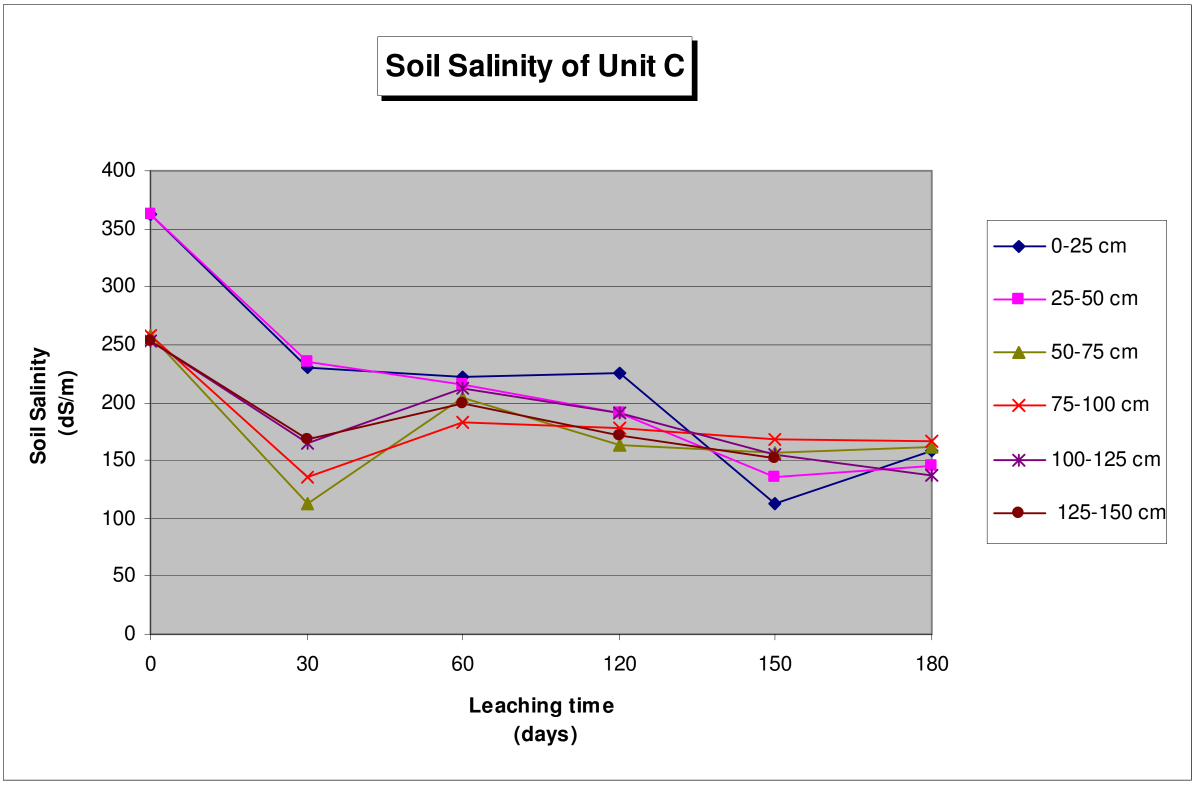

Figure 9: Impact of Leaching Process on Soil Salinity of Unit C

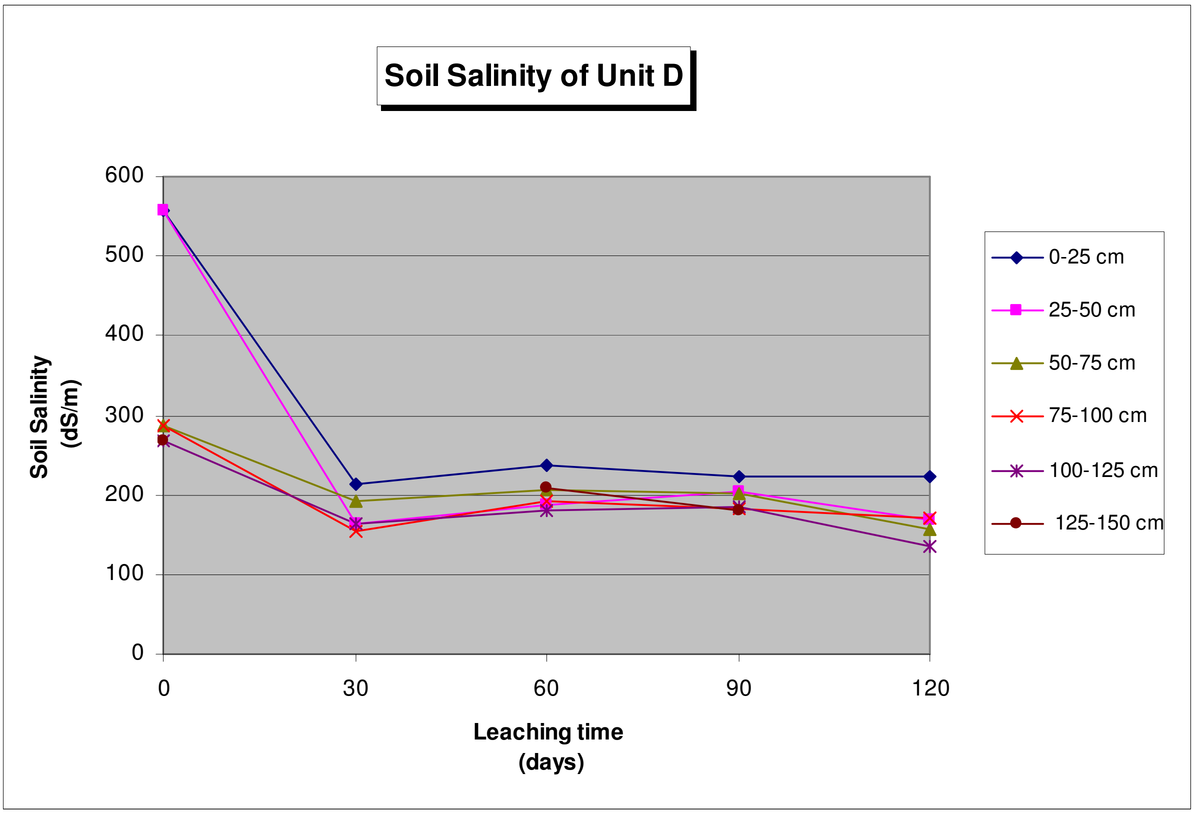

Figure 10: Impact of Leaching Process on Soil Salinity of Unit D

CONCLUSION

It was clear that the recommended strategy of HCMEXS improved consistency, completeness and correctness in compatible with the knowledge of the experts and succeeded to decrease the soil salinity to about 50% within 6 months. It is also expected to complete leaching process within one year from the beginning.

Under such conditions, HCMEXS can be used as an artificial intelligence management tool in accordance with the research results achieved by the problematic heavy clay soil experts and their experiences to help users to make appropriate decisions for heavy clay management so that the goal of improving heavy clay soil can be achieved. It should be taken into consideration that the knowledge base of the system could be improved anytime and be compatible with any new experiences in the field of management of problematic heavy clay soils. It would be undoubted that application of the intelligent computer expert system, to replace the human experts, has a very important practical value.

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