J.Soil Sci. and Agric. Eng., Mansoura Univ., Vol. 9(1): 69 - 76, 2018

Developments of an Expert System for On-Farm Irrigation Water Management Under Arid Conditions

Eid, S. F. M.[1] and M. A. A. Abdrabbo[2]
[1]Agric. Eng. Res. Inst. (AENRI), Agric. Res. Center (ARC), Egypt
[2] Central Lab. for Agric. Climate (CLAC), Agric. Res. Center (ARC), Egypt

ABSTRACT

Arid ecosystem conditions are characterized by water scarcity offer as well due to limited water resources, low irrigation efficiency. Therefore, more efforts had to be carried out in order to find out suitable solutions for this problem and maximizing irrigation unit net return. Therefore, the aim of this investigation was to build; verify; and validate of a developed computer program under arid conditions of Egypt. A developed computer program, ISM-ES (Irrigation Systems Management-Expert System), had been coded by using visual basic 2013 programming language and access software for building up the required database. The developed rule based ES is running under windows media. Moreover, SCWU (seasonal crop-water use); SCWR (seasonal crop-water requirements); WSP (water saving percentage) and IWP (irrigation water productivity) processed as judgment indices in the verification and validation processes. Results revealed that the developed ISM-ES resulted in improving the crop-water production as function of tomato crop and maximize the water unit productivity compared with other ES (IMOC-ES) and conventional treatment based on FAO concepts by using program (CropWat 8.1). Results indicate that SCWR had been decreased under investigated ISM-ES compared with the conventional method approved by FAO at all times of investigations. Meanwhile, there is no significant difference between IMOC-ES and conventional method approved by FAO. On the other hand, by applying the (ISM-ES) to determine the SCWR found that a significant difference. Moreover, data analysis indicated that the developed ISM-ES and IMOC-ES had saved the irrigation water with about 20.49 and 4.88 % compared with conventional method approved by FAO, respectively.

Keywords: Expert system, Rationalizing Index, Irrigation water productivity, Crop-water requirement, Water Save.

INTRODUCTION

Integrated water management in agricultural sector has the majority role for either compensating agricultural resources shortage or to maximize the water unit productivity. These criteria need a highly qualified data in order to achieve its goal. However, an expert system may be considered as an effective tool in these areas of study.

Growing land and water scarcity are the two main structural to Egypt's sustainable agricultural development. The amount of arable land available in the country is almost fixed, with limited capacity to expand it. Hence, the Egyptian government strategy has focused on the sustainable use of existing agricultural land, reclaiming desert areas, and increasing productivity through improved irrigation and cultivation methods. The government could also consider devoting scarce land area to grow crops higher in economic value but lower in water use Isin and Panos, (2017).

There is no doubt that, water is the key factor of the agricultural development processes under arid conditions at Egypt. Although the majority of the water communities is overwhelmed with various problems due to natural climate change cycle; political status and strategies and failure use of agricultural water unit by agricultural producers themselves. One of the most permissive key for solving these problems is that applying the concepts of integrated water management in the agricultural sector. However, integrated water management technologies and attributed techniques requires a highly qualitative data under specified field conditions and status; as well as, a dynamic interaction and interpretation of the data of each criteria. The schematic criteria of the integrated agricultural water management had been illustrated by Arafa (2009).

Optimize the irrigation water usage need an expert to provide farmers by the certain needed water at certain time to irrigate their crops. These experts are rare to found when farmers needed. Also, it doesn't easy to found them in all Egypt villages. Using information and communication technology to develop systems that manage water usage will help in enhancing the irrigation water usage efficiency. Expert systems technology can be used to transfer knowledge from irrigation to both agricultural engineers/officers and farmers which lead to enhance water usage in Egypt, Mahmoud (2009).

Expert systems may be defined as artificial intelligence. It is a new science that deals with the representation, automatic acquisition and use of knowledge. The goal of artificial intelligence is to make computers more useful for reasoning, planning, acting and communicating with humans. Expert System (ES) is one of the newer methods using computer for solving practical problems in agricultures is through the use of expert system. The name comes from the idea that the computer system is programmed to simulate an expert in communication with a client who has a problem to be solved. Various definition of expert systems have been offered by several authors (Rafea, 1998). Arafa et al. (2005) reported that expert systems are typically very domain specific. For example, a diagnostic expert system for troubleshooting computers must actually perform all the necessary data manipulation as a human expert would. The developer of such a system must limit his or her scope of the system to just what is needed to solve the target problem. Special tools or programming languages are often needed to accomplish the specific objectives of the system. The goal of the irrigation expert system is to determine the exact amount of needed water and the exact timing for applying it. The amount of water applied is determined dependent on each user situation Ayman et al. (2014). Due to the successive of expert system technology in solving several problems in the Egyptian agricultural sector, the agricultural water researchers' had conducted several efforts for improving the efficiency of different agricultural water practices by using expert system technology. And hereby different ES programs had been developed such as: ISS-ES, that had been developed by El-Bagoury (2004) ; ChemiGat-ES that had been developed by Doukhan (2011); IMOC-ES that had been developed by El-Tohamy (2016) and TSDI-ES that had been developed by Rageb (2017). Although, all these ESs programs had been developed, the water unit net return did not achieved any improvement, this may be due to the developed ESs had been focused partially on the concepts criteria of agricultural water management and had not achieved the integrated efficiency of the dynamic interaction between the management criteria; variables; parameters and factors, Tripathi (2011).

Therefore, the aim of this investigation was to build; verify; and validate of a developed computer program for integrated-agricultural water management under arid conditions as Egypt.

MATERIALS AND METHODS

1- Integrated-agricultural water management analysis

The process of defining the dynamic network structure which involves information analysis and identifying of the decision making process and activities related to the application priorities of water management and its attributed techniques under extreme field resources had been used for building the suggested rule-based computer program. Information analysis is based on the principle of information engineering used together a reference information model for arable farming. The dynamic network is characterized by the inherent uncertainty and represented the specifying conditional probabilities of each element based on this information model, building network blocks of the dynamic network model are set up as a random variables ranging over possible states, observations, actions and probabilities relations between these criteria variables parameters factors and indices. Representing the temporal aspects of the water management problem, sequences of the relevant variables are used to present probabilities at successive time points.

Fig. (1) presents the building up of the dynamic network and its description of a model structure for description of variables; key factors and qualifiers in order to determine the integrated agricultural water management. However, the interpretation of the dynamic interaction of the abovementioned qualifiers could be described and analyzed according to refer cues, which explained it as following: The conventions followed in the diagram are: ellipses indicate random variables and their probability distributions; ellipse marked "observations" indicates the results of observations; rectangles indicate decisions; diamonds represent utilities; and edges indicate condition dependencies. These variables; key factors and qualifiers of the selection process can be cataloged as follows:

i) Soils: different soils properties and attributed characteristics under diverse filed conditions had been taken into considerations. These variables are physical and chemical properties, soil texture, chemical analysis of different macro and micro-elements (total available and depletion had been considered for managing chemigation with respect to validated crops chemical requirements.

ii) Irrigation water characteristics and attributed systems: different irrigation systems and attributed networks and water characteristics had to be considered for effective management under specific field conditions and status.

iii) Crop patterns and type: crop patterns and types had been selected for validation purposes of the computer program for instance.

iv) Applied technologies and attributed techniques performance analysis criteria: One of these technologies is called chemigation technology, that is highly correlated with irrigation systems and its water characteristics. Also, the other applied technologies and its attributed techniques such as controlling unit systems (manual; semi-automatic and fully automated) have to be taken into considerations. All these effective technologies that effect on the water unit efficiencies have to be taken into considerations.

Meanwhile, the flowchart of the developed computer program had been illustrated in Fig. (2). However, it was divided into three main parts (location data, irrigation water data, and crop data). Each part has some inputs to make the internal calculations for getting the results which will be used.

2- Integrated - agricultural water management computer program system therapy

A developed computer program noted ISM-ES, had been coded by using visual basic 2013 programming language and access software for building up the required database. The developed rule based ES is running under windows media. Moreover, SCWU; applied amounts of irrigation water; crop water production function; water saving percentage and irrigation water productivity had been used as judgment indices in the verification and validation processes for the developed expert system. However, the building up processes and description of the program consequences could be summarized as follows:

i) Definition and Identification of the scope of work

A rule-based computer program named ISM-ES (Irrigation Systems Management-Expert System) was coded and compiled using Microsoft visual basic 2013 language which represents a part of Microsoft Visual studio Express 2013 for windows Desktop Package. The schematic overview showing the key input and output processes and main computational steps needed for the ISM-ES rule-based program. The following steps outline indicated how the ISM-ES program was built and interface user screens of the inputs/output and a conceptualizations of the developed computer program Fig. (3).

a- User interface

A graphic user interface (GUI) is designed to have a clear and soft feel to advance easy use for both experienced users and novice, as farmers, also support them with decision-making related to select the technical specifications of drip irrigation control unit easily and precisely.

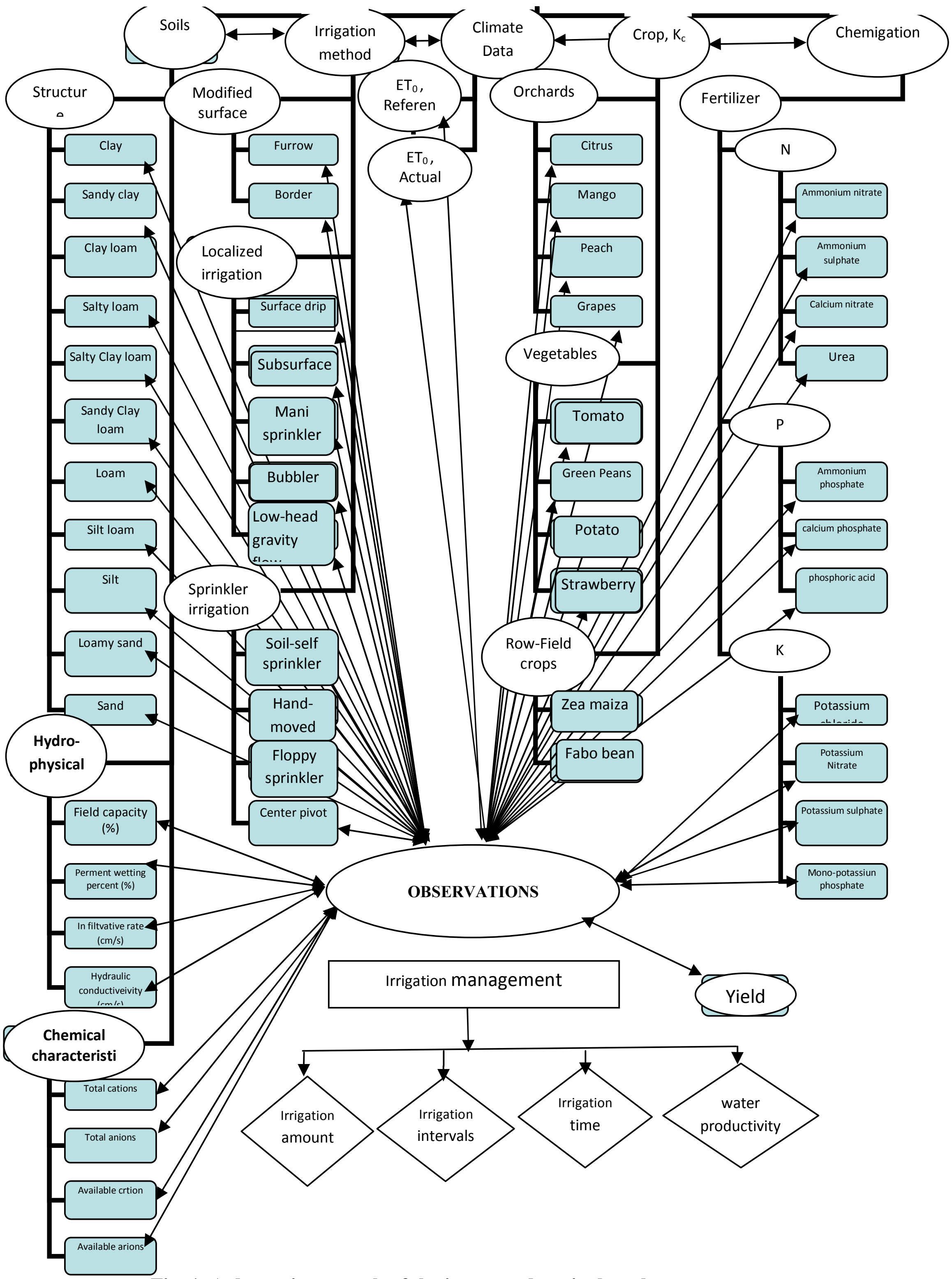

Fig. 1. A dynamic network of the integrated-agricultural water management

b- Structure of ISM-ES

The structure of ISM-ES as rule-based program was designed to choice the technical. The structure of the program consisted of the following:

ii) Conceptualization process

The concept properties are represented as object attributes. The property facts depend on the property value, type and source from which the program gets the property value.

iii) Formalization process

The parameters such as: (ET_o, Kc, ETc and IR) were considered to calculate the water requirements for choosing the components of drip irrigation network. These parameters considered in this study depended on a number of factors and rules.

iv) Verification of the ISM-ES program process

Verification process of the developed ISM-ES outputs (Fig. 3) had been conducted compared with other Expert System noted as IMOC-ES, that had been developed by El-Tohamy (2016) and conventional methods for calculating the crop water use program (CropWat 8.1), which had been approved by FAO (Allen et al., 1998).

v) Validation of the ISM-ES program process

Validation process of the ISM-ES program had been carried out as a field treatments for tomato crop, which had been conducted in a private farm located in El-Nubaria District, Beheira Governorate, Egypt. Soil, water analysis and layout of the experiments described in Tables (1; 2 and 3) and Fig. (2). However, all agronomic practices were done and recommendations of the orchards Crop Research Institute, ARC, MALR,. However, early hybrid tomato crop (seedling transplanting on the end of February and beginning the harvesting on the end of April and beginning of May) considered as a case study for the validation process, during the two successive growing seasons 2015-2016 and 2016-2017.

a- Measurements and Calculated Judgment indices

1- **Crop-water use (CWU, m^3/fed);** and seasonal crop-water requirements (SCWR, m^3/fed), had been calculated and applied based on the climatic data; soil characteristics and crop development under specific field conditions and status, were calculation from;

$$CWU = K_c * ET_0 \text{ , and } SCWR = CWU/E_a$$

2- **Crop-water rationalizing index (kg/m^3),** which represents the effectiveness utilization of each water unit by the tomato crop within the growing development processing periods. However, it calculated according to the following formulae:

$$\text{Crop - Water retionalizing index} = \frac{\text{Observed Biological yield, kg/fed}}{\text{CWU at the growing development time, } m^3/fed}, \quad kg/m^3$$

3- Water judgment Indices:

a- Water saving, %

b- Water productivity

4 –Yield increment percentage

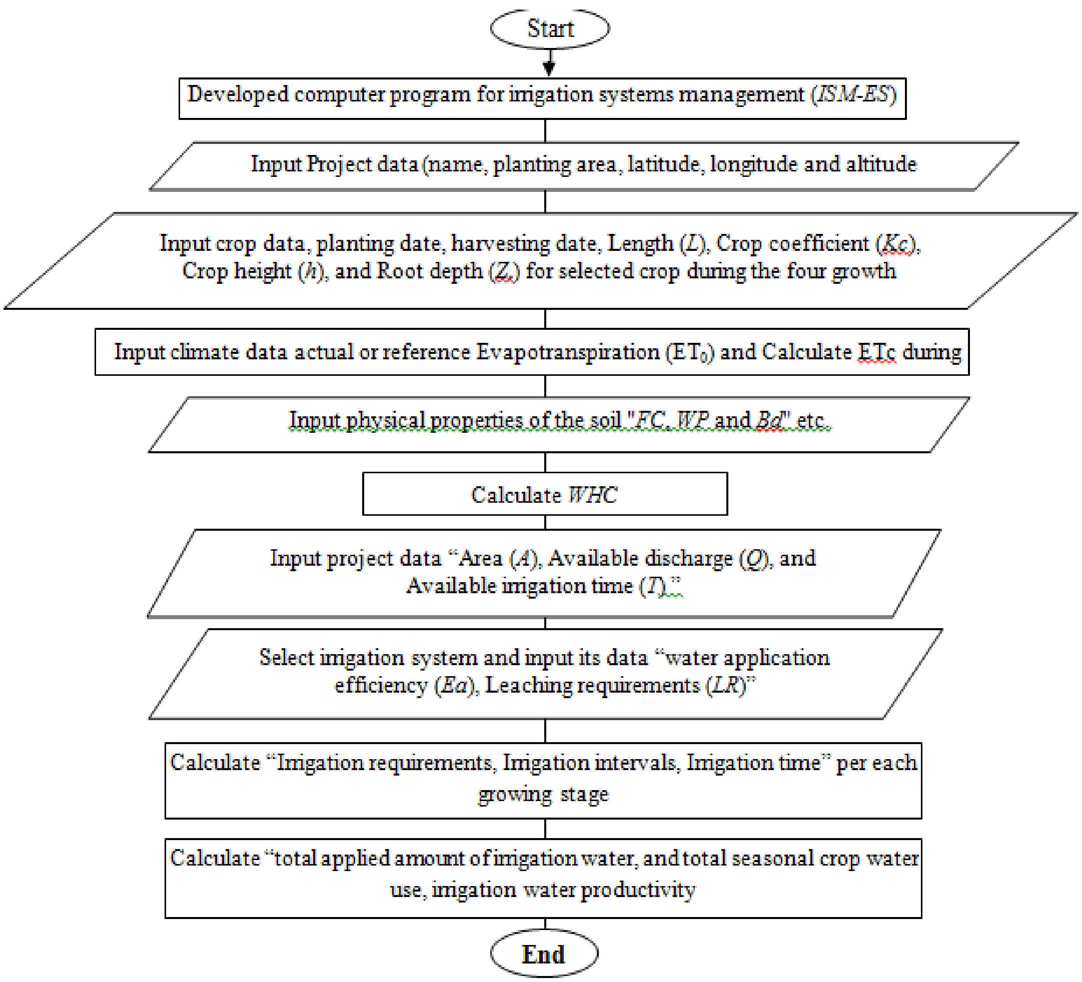

Fig. 2. ISM-ES Schematic processing chart

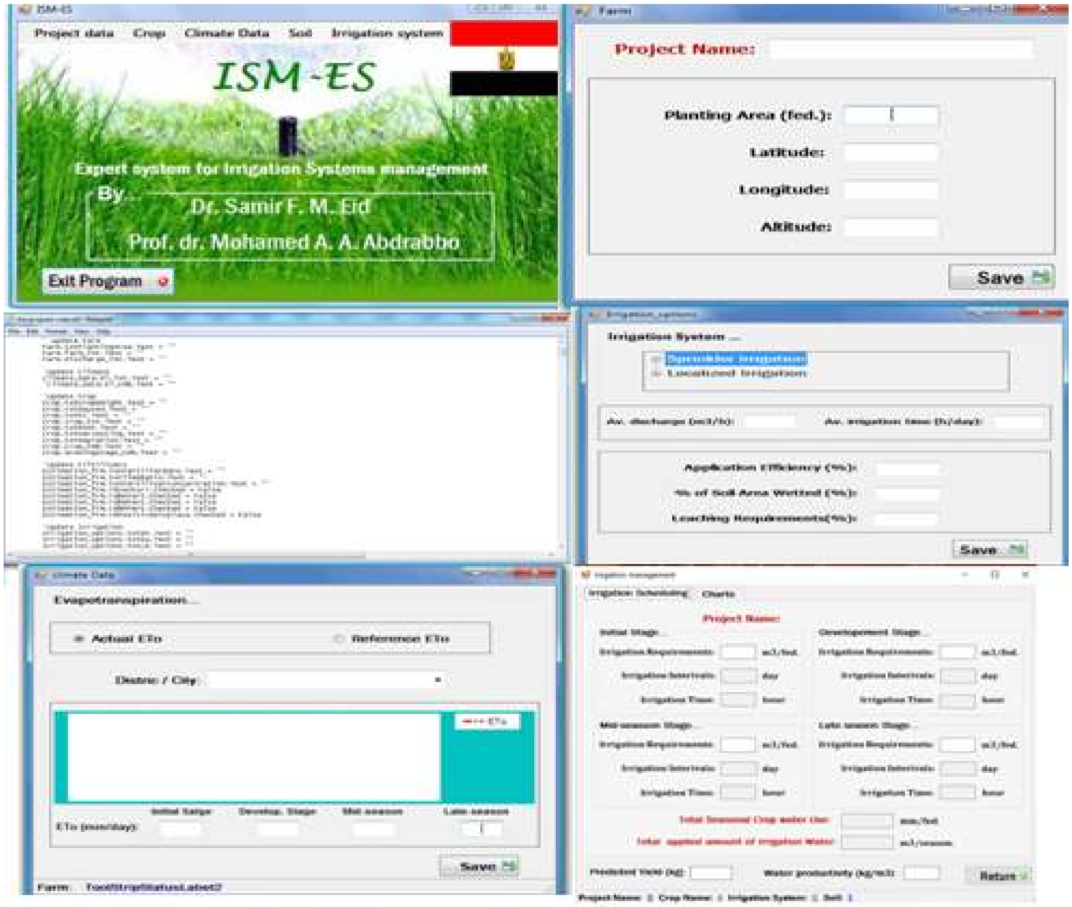

Fig. 3. Interface user screens of the inputs/output and a conceptualizations of the developed computer program (ISM-ES)

Table 1. Soil physical properties of the experimental site

Soil layer, cm	Particle size distribution, % Sand	Silt	Clay	Texture class	B. D (gm/cm^3)	Moisture content by weight, % F. C	P.W.P	A.W
0 –20	94.4	3.6	2.0	Sandy	1.65	8.03	3.33	4.7
20-40	95.0	3.2	1.8	Sandy	1.56	9.13	3.14	5.99
40-60	95.6	3.0	1.4	Sandy	1.44	10.07	2.99	7.08

F.C = Field capacity W.P = Wilting point A.W= Available water B.D= Bulk density

Table 2. Soil chemical characteristics of the experimental site

Soil layer, cm	SAR	pH	E.C, dS/m 25oc	Soluble anions, meq/l CO3--	HCO3-	Cl-	SO4--	Soluble cations, meq/l Ca++	Mg++	Na+	K+
0 –20	1.66	8.23	1.46	0.1	0.93	1.98	9.61	6.23	2.24	3.44	0.51
20-40	1.74	8.11	1.56	0.1	1.15	2.05	9.85	6.45	2.26	3.76	0.58
40-60	1.84	7.97	1.63	0.1	1.33	2.11	10.16	6.65	2.29	3.91	0.65

Table 3. Irrigation water chemical characteristics at the study region

pH	EC, dS/m	Soluble cations, meq/L Ca++	Mg++	Na+	K+	Soluble anions, meq/L CO3--	HCO3-	SO4--	Cl--	SAR, %
7.3	0.60	0.76	0.24	2.6	0.12	0	0.9	0.32	2.51	4.61

pH: power of hydrogen; EC: Electrical conductive, ds/m; SAR: Sodium absorption ratio.

RESULTS AND DISCUSSION

1- Seasonal crop-water requirements management based on computer program (ISM-ES)

Data presented in Table (4) reveal the management efficiency of either CWR and SCWR based on a developed computer program (ISM-ES) compared with each of IMOC-ES and conventional method that had been approved by FAO. However, data analysis indicate that SCWR had been decreased under investigated ISM-ES compared with the conventional method approved by FAO at all times of investigations. The values of total seasonal crop-water requirement (SCWR) were 3139.50, 3120.18 and 2630.66 m^3/fed./seasonal under FAO-based, IMOC-ES and ISM-ES and IMOC-ES respectively. Meanwhile, there is no significant difference between IMOC-ES and conventional method approved by FAO. On the other hand, by applying the SCWR based on the outputs of the developed computer program (ISM-ES), a significant difference had been obtained regarding to SCWR. This may be due to, the difference in the concepts of the criteria that had been considered in the data base, however, it is similar in either IMOC-ES and the conventional method approved by FAO. Meanwhile, the developed ES had the irrigation effectiveness index, that had been developed by Arafa (2016), as a concept for managing on-farm irrigation water, that represents the ratio between irrigation system and water performance and soil characteristics status.

Table 4. Tomato Crop; seasonal crop-water use (CWU; SCWU) and seasonal crop-water requirement (SCWR) m^3/fed. under different investigation methods

Calculation based method	Irrigation water factor, m^3/fed	Tomato growing development stages (Days After Transplanting of seedlings, DAT), day				
		0-21	22-50	51-78	79-107	108-135
	CWU	574.77	306.6	435.75	573.93	778.05
FAO-based	SCWU	606.12	367.99	489.89	680.78	680.78
	Applied amounts (SCWR)	673.47	408.87	544.32	756.42	756.42
	CWU	574.77	306.6	435.75	573.93	778.05
IMOC-ES	SCWU	551.50	341.71	512.95	580.97	821.02
	Applied amounts (SCWR)	612.78	379.68	569.94	645.54	912.24
	CWU	574.77	306.6	435.75	573.93	778.05
ISM-ES	SCWU	500.58	266.21	414.23	529.56	709.62
	Applied amounts (SCWR)	544.11	289.36	450.25	575.61	771.33

a- Comparative analysis regarding the SCWU between ISM-ES; IMOC-ES; and conventional method approved by FAO

Data presented in Figs. (8; and 9) indicate the regression analysis between the investigated methods. However, the regression coefficient (R^2) was ranged from 0.9768 and 0.8358 with ISM-ES and IMOC-ES; and with ISM-ES and conventional method approved by FAO respectively. Meanwhile, the observed correlation equations may be stated as:

$$SCWR_{IMOC-ES} = 0.93\ SCWR_{ISM-ES} - 39.85 \quad ....(1) \quad (R^2 = 0.9768)$$

$$SCWR_{FAO-based} = 1.10\ SCWR_{ISM-ES} - 137.38 \quad ....(2) \quad (R^2 = 0.8358)$$

The above mentioned observed data indicate the ability of applying computer program technology for managing on-farm irrigation water under specified field conditions with high accuracy of investigation. This means that, the maximization of on-farm irrigation water unit could be achieved under arid conditions by applying ES technology.

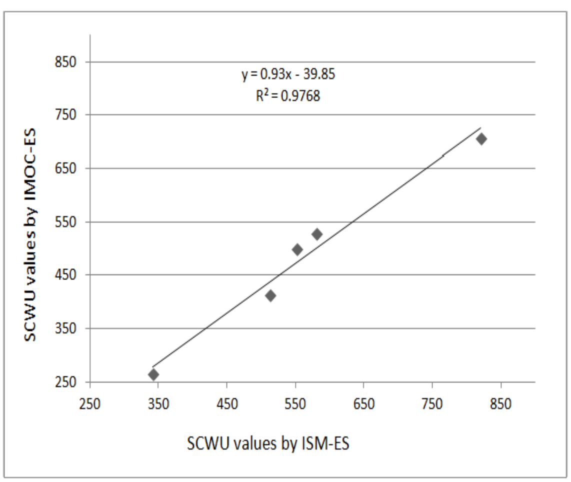

Fig. 8. the regression and correlation analysis between the seasonal crop-water use (SCWU) ISM-ES and IMOC-ES

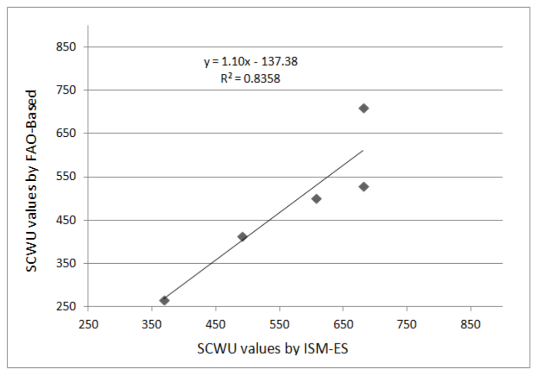

Fig. 9. The regression and correlation analysis between the seasonal crop-water use (SCWU) ISM-ES and FAO-Based

b- Crop-Water rationalizing index (CWRI) and water saving percentage under different investigated methods

Monitoring of irrigation water uses, which reveal the time detection within the growing development processing of the crop plays a crucial role in maximizations of the net return of unit; therefore, calculating CWRI may be an effective way of investigation of this aim. Hereby, data presented in Table (5) indicate that the highest CWRI had been differed according to the management criteria of investigation; however, it was 38.84 kg/m^3 at the growing development days of 51-78 under conventional method of investigation. This mean that, with a point of view of water uses, all other growing days after this period could be considered as non-economic. On the other hands, CWRI was 40.05 and 52.9 kg/m^3; at the growing development days of 79-107 under IMOC-ES and ISM-ES, respectively. Regarding, the water saving percentage, data analysis presented in Fig. (10) indicate that the ISM-ES and IMOC-ES had saved the irrigation water with about 20.49 and 4.88 % compared with conventional method approved by FAO, respectively.

Table 5. Tomato Crop-Water Rationalizing Index (CWRI) within different growing development days under different investigation methods

Calculation based method	Judgment Index	Tomato growing development stages (Days After Transplanting of seedlings, DAT), day				
		0-21	**22-50**	**51-78**	**79-107**	**108-135**
FAO-based	SCWR, m^3/fed	673.47	408.87	544.32	756.42	756.42
	Biological Yield, Mgram/fed	0.42	4.2	15.88	22.74	18.7
	CWRI, kg/m^3	0.62	10.27	38.84	30.06	20.2
IMOC-ES	SCWR, m^3/fed	612.78	379.68	569.94	645.54	912.24
	Biological Yield, Mgram/fed	0.52	6.18	18.2	26.5	20.93
	CWRI, kg/m^3	0.85	16.28	31.93	40.05	22.94
ISM-ES	SCWR, m^3/fed	544.11	289.36	450.25	575.61	771.33
	Biological Yield, Mgram/fed	0.63	11.37	23.02	30.45	23.14
	CWRI, kg/m^3	1.16	39.29	51.13	52.9	30.0

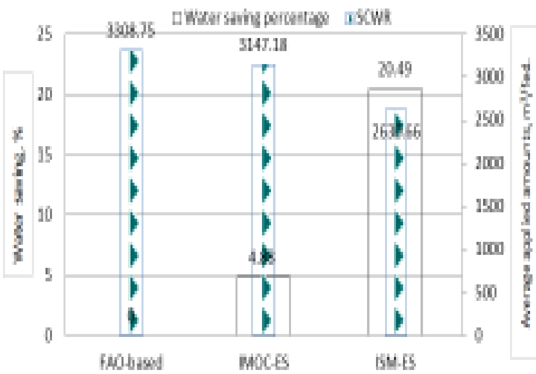

Fig. 10. The water saving percentage and Average applied amounts water m^3/fed for the ISM-ES, IMOC-Es and FAO-Based method

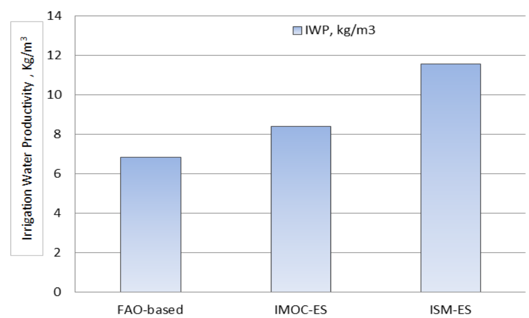

Fig. 12. Irrigation water productivity (IWP, kg/m^3) under FAO-based; IMOC-ES and ISM-ES method

2- Yield and irrigation water productivity (IWP)

Data presented in Fig. (11) indicate that the yield were 22.74, 26.50 and 30.45 Mgram/fed. under conventional method approved by FAO; IMOC-ES and ISM-ES respectively. So the economic fruit yield of tomato crop under the studies area conditions had been increased with about 16.53 and 33.91% under IMOC-ES and ISM-ES compared with conventional method approved by FAO, respectively. Meanwhile, Fig. (12) show that the irrigation water productivity (IWP) values were 6.87, 8.42 and 11.58 kg/m^3 under conventional method approved by FAO; IMOC-ES and ISM-ES respectively.

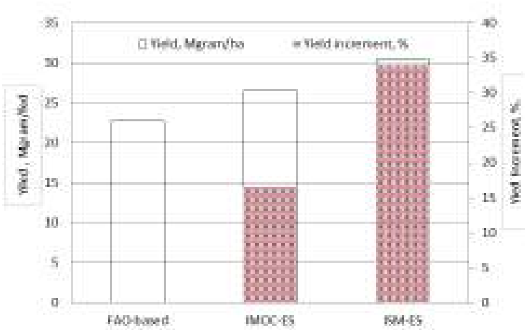

Fig. 11. Yield (Mgram/fed.) and yield increment, % under FAO-based; IMOC-ES and ISM-ES method

REFERENCES

Allen, R. G., Pereira, L. S., Rase, D., and Smith, M., 1998. Crop evapotranspiration: Guidelines for computing crop requirements. United Nations, FAO, Irrigation and Drainage Paper No. 56, Rome, Italy.

Arafa, Y. E.; E. A. Sahhar; A. A. Rafea and A. M. Gindy, 2005. Expert system for application priorities of localized irrigation systems, 9th Conf. of Agric. Develop. Res., Fac. of Agric., Ain Shams Univ., Cairo, Egypt: 208-218.

Arafa, Y. E., 2009. Recent approaches for maximizing irrigation water uses and sustainable agricultural development. Congress of Arab. Food security, 17-20 March, El-Khartoum, Sudan (**Review article**).

Arafa, Y. E., 2016. A developed criterion for rationalizing on-farm irrigation water uses under arid ecosystems conditions. Int. J. of Irrigation and Drainage systems Eng., 5(2):1-7.

Ayman N., Mona N.; and Maryam H., 2014. Irrigation Expert System for trees. International Journal of Engineering and Innovative Technology (IJEIT) 3, (8): 170-175.

Doukhan, A. Z., 2011. Expert system for managing chemigation systems. Ph. D. Thesis, Agric. Eng. Dept., Fac. of Agric., Ain Shams Univ., Cairo, Egypt, 38-45.

El-Bagoury, K. F., 2004. The use of expert system to improve farm irrigation technologies for maximizing water use efficiency of field crops under drought conditions in Egypt. Ph. D. Thesis, Agric. Eng. Dept., Fac. of Agric., Ain Shams Univ., Cairo, Egypt: 110-115.

El-Tohamy, K. M., 2016. An Expert System for Managing On-Farm Irrigation Water of Some Oil Crops. M.Sc. Thesis, Department of Agricultural Engineering, Faculty of Agriculture, Ain Shams University: 125.

Isin Tellioglu and Panos Konandreas, 2017. Agricultural Policies, Trade and Sustainable Development in Egypt. ICTSD and FAO.

Mahmoud M., 2009. Irrigation and fertilization expert system for vegetables based on geographical information system. Proc. IADIS International Conference on Intelligent Systems and Agents, : 21-23.

Rafea, A. A., 1998. Egyptian research program for developing expert systems in agriculture, 7th Int. Conf. on Comp. in Agric., Orlando, FL, USA,: 1028-1046.

Ragab, S. A., 2017. An expert system for selecting the technical specifications of drip irrigation control unit. M.Sc. Thesis, Dept. of Agric. Eng., Fac. of Agric., Ain Shams University: 115.

Tripathi K. P., 2011. A review on knowledge-based expert systems: concept and architecture, IJCA special Issue on Artificial Intelligence Techniques-Novel Approaches & Practical Applications, 4: 19-23.

تطوير نظام خبير لإدارة مياه الري الحقلي تحت الظروف القاحلة.

سمير فتوح محمد عيد [1] و محمد عبد ربة أحمد[2]

[1]معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية – وزارة الزراعة ـ مصر.

المعمل المركزي للمناخ الزراعي – مركز البحوث الزراعية – وزارة الزراعة ـ مصر.

ادارة مياه الري الحقلي لها من الأهمية الأولي لمجابهة مخاطر نقص الموارد المائية تحت الظروف البيئية القاحلة مثل مصر. لذا فإن البيانات الدقيقة والمؤهلة يجب أن تجمع وتدمج معا وتحلل جيدا للوصول إلي الإدارة الجيدة للممارسات المائية الزراعية.بناءا علي ذلك فإن الهدف من الدراسة هو بناء وتطوير وتقويم برنامج حاسوبي لتحسين وإدارة مياه الري الحقلي تحت الظروف البيئية القاحلة.تم بناء وتكوين برنامج حاسوبي (نظام خبير) اطلق عليه ISM- ES وذلك باستخدام لغة visual basic 6 programming software تحت بيئة النوافذ. وقد تم استخدام أدلة الإحتياجات المائية السنوية للنباتات ودالة الإنتاج المحصولي ـ المائية وكفاءة استخدام المياه للحكم علي جودة مخرجات البرنامج مقارنة بنظيرتها التجريبية التقليدية المعتمدة من FAO.أوضحت النتائج أن الاحتياجات المائية الكلية لمحصول الطماطم كانت 2630.66 و 3120.18 و 3139.50 عند استخدام البرنامج المطورISM- ES و برنامج IMOC-ES و FAO-based علي الترتيب، واستنتج علاقة خطية بين دالة الإنتاج المحصولي-المائي بين البرنامج الحاسوبي ISM- ES والبرنامج IMOC-ES وكذلك FAO-based والتي أعطت معنوية R^2= 0.9768 and 0.8358 وكانت العلاقة هي:

$SCWR_{IMOC\text{-}ES} = 0.9328\ SCWR_{ISM\text{-}ES} - 39.85$ ....(1) $R^2 = 0.9768$

$SCWR_{FAO\text{-}based} = 1.0996\ SCWR_{ISM\text{-}ES} - 137.38$............(2) $R^2 = 0.8358$

وتشير النتائج إلي قدرت البرنامج (ISM- ES) علي إدارة مياه الري في المزارع بدقة عالية وهذا يعني انه يمكن الوصول لأقصي قدر ممكن من وحدة مياه الري في ظل الظروف القاحلة مثل مصر.وتبين ارتفاع دالة ترشيد المياه لأعلي قيمة 38.84 كجم/م^3 عند عمر محصولي 51-79 يوم باستخدام FAO-based بينما كانت 40.5 و 52.9 كجم/م^3 باستخدام البرنامج الحاسوبي ISM- ES والبرنامج IMOC-ES علي الترتيب عند عمر المحصول 79- 107يوم. وفيما يتعلق بنسبة توفير المياه فإن تحليل البيانات أوضحت وفر في مياه الري مقداره 20.49 و4.88 للبرنامج الحاسوبي ISM- ES والبرنامج IMOC-ES علي الترتيب بالمقارنة مع برنامج FAO-based. وفيما يتعلق بكفاءة استخدام المياه أظهرت تحليل البيانات المتحصل عليها تحسين كفاءة استخدام المياه فكانت 6.87 و 8.42 و 11.58 طن/فدان للبرنامج الحاسوبي ISM- ES والبرنامج IMOC-ES وبرنامج FAO-based علي الترتيب.وتشير النتائج إلي قدرة البرنامج (ISM- ES) علي إدارة مياه الري في المزارع بدقة عالية وهذا يعني انه يمكن الوصول لأقصي قدر ممكن من وحدة مياه الري في ظل الظروف القاحلة مثل مصر.

الكلمات المفتاحية: نظام خبير - نظم الري الحقلي ـ الاحتياجات المائية الموسمية للنبات ـ كفاءة استخدام المياه ـ الظروف القاحلة ـ توفير المياه.