SOFTWARE APPLICATION FOR IRRIGATION WATER MANAGEMENT OPTIMIZATION

APLICATIE SOFTWARE PENTRU OPTIMIZAREA MANAGEMENTULUI APEI PENTRU IRIGATII

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***Abstract:** During the last decade the climate started to get warmer and large area of land were affected by drought. On the other hand, the global economy started to fall and more and more people are facing poverty and starvation. In order to face these challenges it is important to develop a sustainable agriculture, able to feed the growing population. In this situation, the water management became a major issue in all human activities. This paper aim is to present a way to improve water management for irrigation, using a software application based on Penman-Monteith equation as method for estimating reference crop evapotranspiration. The application assesses the crop water requirements and offers support for designing an efficient schedule for irrigation. The computation is carried out using local climatic data and crop characteristics as inputs. This application is easy to use, but assumes that climatic data and crop characteristics are available. To reach this goal, 144 countries all over the world gathered information provided by a total of 3262 meteorological stations and developed a data-base available on-line for free. Unfortunately, Romania didn't join this international effort and, as result, the necessary information for our country is difficult to find. This paper describes the way the application works and shows how to get the necessary input data. A basic example, for an arid area in Romania, is presented in the paper. It points out the application functions and its importance for the development of some improved practices for irrigation. Further tests should be carried out to analyze the application results in irrigation water management and its efficiency in crop growing.*

***Rezumat**: In timpul ultimei decade, clima a devenit mai calda si mari suprafete de teren au fost afectate de seceta. Pe de alta parte, economia globala a intrat in declin si din ce in ce mai multi oameni se confrunta cu saracia si foametea. Pentru a face fata acestor provocari, este importanta dezvoltarea unei agriculturi durabile, capabila sa asigure hrana unei populatii in crestere. In aceasta situatie, managementul apei devine o problema importanta in toate activitatile umane. Scopul acestei lucrari este de a prezenta un mod de a imbunatati managementul apei pentru irigatii, utilizand o aplicatie software care se bazeaza pe ecuatia Penman-Monteith pentru estimarea evapo-transpiratiei de referinta. Aplicatia determina necesarul de apa al culturilor si ofera suport pentru proiectarea unor scheme eficiente de irigatii, folosind date climatice locale si caracteristicile culturilor ca date de intare. Aplicatia este usor de utilizat, dar presupune ca datele climatice si caracteristicile culturilor sunt disponibile. Pentru a atinge acest obiectiv, 144 de tari din intreaga lume au strans informatii furnizate de un total de 3262 statii meteorologice si s-a dezvoltat o baza de date care este disponibila gratuit pe Internet. Din pacate, Romania nu s-a alaturat acestui efort si, prin urmare, informatiile referitoare la tara noastra sunt greu de gasit. Lucrarea de fata descrie modul de utilizare al aplicatiei. In lucrare este ilustrat un exemplu pentru o zona arida din Romania, care evidentiaza functiile aplicatiei si importanta ei pentru dezvoltarea unor practici imbunatatite de irigare. Pe viitor este necesar sa se realizeze mai multe testari pentru a analiza eficienta aplicatiei in managementul apei pentru irigatii.*

***Key words**: irrigation water management, reference evapotranspiration, crop water requirements*
***Cuvinte cheie**: managementul apei pentru irigatii, evapotranspiratia de referinta, necesarul de apa al culturilor*

INTRODUCTION

In the last decades, people influenced more and more the environment, determining the occurrence of changes, which became global phenomena, due to their spreading and largeness, closely linked between them. The most important phenomenon is the global warming, followed by water resources depletion and pollution. The global warming effects are: climate changes, increasing of sea water level, changes in agriculture.

The global warming affects Romania too, the major effects being: warmer and dryer winters, increasing of the extreme meteorological events frequency like hot summers, tornados and floods. Meteorological registrations show a tendency of desertification on an area of 3 million hectares, of which 2,8 million hectares are cultivated land. Hydrological regime changed as well, causing major consequences to the environment:

- evaporation increased during summer time as a result of the air temperature increase;
- soil humidity decreased during vegetation season with 20-30%, having as effect the hydric stress increase on plants and the agricultural production decrease.

In order to face this situation and prevent its effects, it is necessary to be able to model the phenomena, study their effects on agricultural production and adopt an adequate water management for irrigation.

The paper presents CropWat application, which is a useful instrument in modelling these processes and provide support for irrigation water management and for finding efficient schedule for irrigation.

MATERIAL AND METHODS

CropWat is meant as a practical tool to help agronomists and irrigation engineers to carry out standard calculations for evapotranspiration and crop water use studies, and more specifically the design and management of irrigation schemes. CropWat allows developing recommendations for improved irrigation practices and plans of irrigation schedules under varying water supply conditions.

In the frame of CropWat application, the evapotranspiration is computed with Penman-Monteith equation, using the evaluation method of the crop reference evapotranspiration recommended by F.A.O. This method is used both for humid and dry climate.

The reference evapotranspiration concept was introduced to study the evaporation requirement independent of the crop type, its growth and the agricultural practices.

Penman-Monteith equation, on which the estimations are made, is the following:

$$Et_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)}$$, where:

ET_o = reference evapotranspiration [mm/day],
R_n = net radiation at the crop surface [MJ /m^2 day],
G = soil heat flux density [MJ/ m^2 day],
T = mean daily air temperature at 2 m height [°C],
u_2 = wind speed at 2 m height [m/s],
e_s = saturation vapour pressure [kPa],
e_a = actual vapour pressure [kPa],
e_s-e_a = saturation vapour pressure deficit [kPa],
Δ = slope vapour pressure curve [kPa/°C],
γ = psychometric constant [kPa/ °C].

In the above equation, 0.408 values represent the conversion of the net radiation R_n expressed in MJ/m^2.day in equivalent evapotranspiration in mm/day. Because the soil heat flux is small in comparison with R_n, particularly when the surface is covered with vegetation and the time steps are of 24 hours per day or longer, the soil heat flux G is ignored and it is assumed to be zero when the evapotranspiration is computed.

Calculations procedures of the water requirement are based on FAO methodology presented in the paper **„Irrigation and Drainage – Crop water requirements and Yield response to water"**. The crop water requirements and the irrigation requirements are performed using as inputs: climatic data and crop patterns data.

The crop patterns (crop coefficient K_c, percentage of cultivated land surface etc.) can be inserted by the user or taken from a data base, if it exists. It is also necessary to load the data regarding the rainfalls (total average monthly rainfall, monthly effective rainfall calculated using "intensity-duration-frequency method) for the studied area and data regarding the soil type where the crop is cultivated. K_c varies mainly with the crop patterns, which are: crop height, cultivated soil surface reflex (Albedo), crop development stage, evaporation on soil level, and only in a limited way depending on climate parameters. This fact allows transferring the K_c standard values in different areas and climate zones.

144 countries all over the world gathered information provided by a total of 3262 meteorological stations and developed a data-base for climatic data, which is available on-line for free. Unfortunately, Romania didn't join this international effort and, as result, the necessary information for our country is difficult to find. That is why this model of the soil water management is not so easily accessible to the final users in agriculture. Because of these limitations, the application can be used only by a limited group of specialists which have the necessary specific knowledge and measurements or statistical data.

We present an example of the application use for a wheat crop in Alexandria area.

RESULTS AND DISCUSSIONS

In the first stage we have to insert the climate data for Alexandria and the application computes the reference evapotranspiration and the effective rainfall.

CropWat 4 Windows Ver 4.3

Climate and ETo (grass) Data

Data Source: C:\CROPWATW\CLIMATE\ALEXA.PEM

Country : Romania — Station : Alexandria

Altitude: 47 meter(s) above M.S.L.

Latitude: 43.52 Deg. (North) — Longitude: 25.50 Deg. (East)

Month	MaxTemp (deg.C)	MiniTemp (deg.C)	Humidity (%)	Wind Spd. (Km/d)	SunShine (Hours)	Solar Rad. (MJ/m2/d)	ETo (mm/d)
January	0.5	-6.9	89.0	259.2	1.9	4.6	0.49
February	3.7	-4.6	87.0	267.8	3.3	7.4	0.79
March	10.7	-0.4	78.0	302.4	4.6	11.4	1.82
April	18.5	5.4	71.0	276.5	6.9	17.2	3.34
May	23.8	10.5	71.0	233.3	7.9	20.6	4.33
June	27.5	13.8	70.0	198.7	9.1	23.0	5.06
July	30.0	15.6	67.0	190.1	10.4	24.3	5.58
August	29.8	14.8	68.0	172.8	10.1	22.1	4.94
September	25.7	11.1	70.0	181.4	8.6	17.1	3.60
October	18.6	5.9	76.0	207.4	5.2	10.1	2.05
November	10.7	1.9	85.0	233.3	2.4	5.3	0.94
December	3.6	-3.5	89.0	207.4	2.1	4.2	0.46
Average	16.9	5.3	76.8	227.5	6.0	14.0	2.78

Figure 1. The reference evapotranspiration in Alexandria area

Cropwat 4 Windows Ver 4.3

ETo and Rainfall Data

Data Source: C:\CROPWATW\CLIMATE\ALEXA.CRM

Month	ETo (mm/d)	Total Rainfall (mm/month)	Effective Rain (mm/month)
January	0.49	38.4	36.0
February	0.79	22.4	21.6
March	1.82	33.4	31.6
April	3.34	44.7	41.5
May	4.33	63.1	56.7
June	5.06	55.1	50.2
July	5.58	79.3	69.2
August	4.94	50.5	46.4
September	3.60	78.0	68.3
October	2.05	34.1	32.2
November	0.94	34.0	32.2
December	0.46	27.7	26.5
Total (mm/Year)	1020.09	560.7	512.4

N.B. Effective rainfall calculated using the USSCS formulas:

Effective R. = (125 - 0.2 * Total R.)* Total R. / 125 ... ... (Total R. < 250 mm/month),

Effective R. = 0.1 * Total R. - 125 ... (Total R. > 250 mm/month).

Figure 2. The effective rainfall depending on reference evapotranspiration and total rainfall

Based on these preliminary data, crop water requirements are calculated in the next step.

Crop Water Requirements Table

Time Step (Days): 15 Update Report...

[All Blocks] Irrigation Efficiency (%): 80 Close

Date	ETo (mm/period)	Crop Area (%)	Crop Kc	CWR (ETm) (mm/period)	Total Rain (mm/period)	Effect. Rain (mm/period)	Irrig. Req. (mm/period)	FWS (l/s/ha)
3/3	24.54	99.00	0.30	7.29	16.56	15.66	0.00	0.00
18/3	33.89	99.00	0.32	10.90	18.95	17.68	0.00	0.00
2/4	43.80	99.00	0.59	25.97	21.62	19.93	6.04	0.06
17/4	53.61	99.00	0.92	49.62	24.38	22.25	27.37	0.26
2/5	62.69	99.00	1.17	73.59	27.01	24.45	49.14	0.47
17/5	70.47	99.00	1.19	83.71	29.33	26.39	57.32	0.55
1/6	76.45	99.00	1.19	90.82	31.18	27.92	62.90	0.61
16/6	80.24	99.00	1.00	80.43	32.42	28.94	51.48	0.50
1/7	81.55	99.00	0.66	53.55	32.98	29.39	24.17	0.23
Total	527.25			475.90	234.42	212.62	278.43	[0.30]

Figure 3. Crop water requirements for spring wheat cultivated in Alexandria area

In the end, using the above computed data together with the soil characteristics, the irrigation schedule is designed.

Irrigation Scheduling Report

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* Crop Data:

- Crop # 1 : Spring Wheat
- Block # : 1
- Planting date: 3/3

* Soil Data:

- Soil description : Medium
- Initial soil moisture depletion: 0%

* Irrigation Scheduling Criteria:

- Application Timing: Irrigate when 100% of readily soil moisture depletion oc
- Applications Depths:Refill to 80% of readily available soil moisture.
- Start of Scheduling: 3/3

Date	TAM (mm)	RAM (mm)	Total Rain (mm)	Efct. Rain (mm)	ETc (mm)	ETc/ETm (%)	SMD (mm)	Interv. (Days)	Net Irr. (mm)	Lost Irr. (mm)	User Adj. (mm)
7/3	50.4	25.2	5.5	1.7	0.5	100.0%	0.5				
12/3	60.9	30.5	5.8	2.4	0.5	100.0%	0.5				
17/3	71.4	35.7	6.0	2.7	0.6	100.0%	0.6				
22/3	81.9	41.0	6.3	3.0	0.6	100.0%	0.6				
27/3	92.4	46.2	6.6	3.3	0.7	100.0%	0.7				
1/4	102.9	51.5	6.9	3.6	0.8	100.0%	0.8				
6/4	113.4	56.7	7.2	4.7	1.2	100.0%	1.2				
11/4	123.9	62.0	7.5	7.2	1.8	100.0%	1.8				
16/4	134.4	67.2	7.8	7.8	2.3	100.0%	4.4				
21/4	144.9	72.5	8.1	8.1	3.0	100.0%	9.9				
26/4	155.4	77.7	8.5	8.5	3.7	100.0%	18.5				
1/5	165.9	83.0	8.8	8.8	4.4	100.0%	30.4				
6/5	168.0	84.0	9.0	9.0	4.7	100.0%	44.3				
11/5	168.0	84.0	9.3	9.3	4.9	100.0%	59.1				
16/5	168.0	84.0	9.6	9.6	5.1	100.0%	74.6				
18/5	168.0	84.0	0.0	0.0	5.2	100.0%	84.9	76	68.1	0.0	
21/5	168.0	84.0	9.8	9.8	5.3	100.0%	22.7				
26/5	168.0	84.0	10.1	10.1	5.5	100.0%	39.7				
31/5	168.0	84.0	10.3	10.3	5.6	100.0%	57.3				
5/6	168.0	84.0	10.5	10.5	5.8	100.0%	75.5				
7/6	168.0	84.0	0.0	0.0	5.8	100.0%	87.2	20	70.4	0.0	
10/6	168.0	84.0	10.6	10.6	5.9	100.0%	23.8				
15/6	168.0	92.4	10.8	10.8	5.3	100.0%	40.8				
20/6	168.0	100.8	10.9	10.9	4.6	100.0%	54.3				
25/6	168.0	109.2	11.0	11.0	3.9	100.0%	64.2				
30/6	168.0	117.6	11.1	11.1	3.2	100.0%	70.4				
5/7	168.0	126.0	11.1	11.1	2.4	100.0%	72.9				
10/7	168.0	134.4	11.1	11.1	1.6	100.0%	71.4				
Total			230.3	207.1	417.0	100.0%			138.5	0.0	0.0

* Legend:

TAM = Total Available Moisture = (FC% - WP%)* Root Depth [mm].
RAM = Readily Available Moisture = TAM * P [mm].
SMD = Soil Moisture Deficit [mm].

Figure 4. Irrigation schedule for the wheat crop in Alexandria area

CONCLUSIONS

The application main goal is to improve the agricultural practices in order to increase quantitatively and qualitatively the vegetal production and it aims to contribute to the following issues:

- development of the estimation methods to forecast the climate variability on agricultural crops;

- application of the climate data to estimate the water balance in the soil and the agricultural production;
- decision improvement to diminish the negative effects of the climate changes on crops;
- comparison between the simulated results in the assumed climatic conditions with the real ones, in order to quantify the application efficiency and the irrigation schedules proposed.

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