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A STUDY OF CLIMATE CHANGES IMPACT ON THE QUANTITIES OF WATER USED FOR IRRIGATION

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ABSTRACT

The assessment of water needs is one of the key elements in the development of the water budget Which is a very important issue in the field of irrigation. Assessing the water needs is the first essential step to develop future development plans and planning the strategic planning of irrigation projects. This paper presents a study on the irrigation water needs and the impact of climate change on the quantities of water used for irrigation. This study was conducted on three crops in Marsa Matrouh, which are banana, sweet pepper and potato. The method used to do so is “Cropwat” based on some input information such as climate, rain, crop, soil and crop pattern for the study area. The Penman-Monteith method was used to estimate ETo was calculated with the following basic data temperature, humidity, sunshine and wind speed. In this study, crop coefficients (Kc) were applied to different growth stages of crops (banana, sweet pepper, and potato) to control and estimate actual evaporation ETc through the through a water balance of the irrigation water requirements (IR). The results showed the annual (ETo) was estimated at 1109.6 mm. The lowest daily value of ETo of 1.37 mm, was observed in December month, while the highest value 4.51 mm was observed in June. One of the factors that affect the increase in evapotranspiration (ETo) and thus the irrigation needs is temperature, as it has a great direct impact on plants. An important factor in the occurrence of soil moisture is precipitation, as this process plays a major role in increasing crop productivity. Through The crop evapotranspiration ETc and the crop irrigation requirements calculations, irrigation projects can then be scheduled in different seasons for water use efficiency based on these results. The net irrigation demand, the gross irrigation demand and irrigation interval for the various crops grown have been computed. In this paper, the author briefed using CR+OPWAT 8.0 to assess the water needs and provide general guidance to produce three kinds of crops banana crop, sweet pepper crop, and potato crop, all in Ma-trouh Governorate located in the north coast in Egypt.

KEYWORDS: Irrigation, Evapotranspiration , Rainfall, and Water Resources Management.

دراسة تأثير التغيرات المناخية على كميات المياه المستخدمة في الري

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الملخص

يعتبر تقييم الاحتياجات المائية أحد العناصر الأساسية في تطوير الميزانية المائية وهي قضية مهمة للغاية في مجال الري ، وتعد الخطوة الأساسية الأولى لتطوير خطط التنمية المستقبلية والتخطيط الاستراتيجي لمشاريع الري. يقدم هذا البحث دراسة عن احتياجات مياه الري وتأثير تغير المناخ على كميات المياه المستخدمة للري. أجريت هذه الدراسة على ثلاثة محاصيل بمحافظة مرسى مطروح

وهي الموز والفلفل الحلو والبطاطس. الطريقة المستخدمة للقيام بذلك هي "Cropwat" بناءً على بعض المعلومات مثل المناخ والمطر والمحاصيل والتربة ونمط المحاصيل لمنطقة الدراسة. تم استخدام طريقة Penman-Monteith لتقدير وحساب ETo باستخدام البيانات الأساسية درجة حرارة ، والرطوبة ، وضوء الشمس وسرعة الرياح ، تم تطبيق معاملات المحاصيل (Kc) على مراحل النمو المختلفة للمحاصيل (الموز والفلفل الحلو والبطاطس) لحساب التبخر الفعلي ETc من خلال التوازن المائي لمتطلبات مياه الري. أظهرت النتائج أن (ETo) السنوي قدر بـ ١١٠٩,٦ ملم. لوحظ أدنى قيمة يومية لـ ETo عند ١,٣٧ ملم ، في شهر ديسمبر ، بينما لوحظ أعلى قيمة ٤,٥١ ملم في يونيو. من العوامل التي تؤثر على زيادة التبخر النتح (ETo) وبالتالي احتياجات الري هي درجة الحرارة ، وايضا تعتبر الأمطار من العوامل المهمة في حدوث عملية رطوبة التربة ، حيث تلعب هذه العملية دورًا رئيسيًا في زيادة إنتاجية المحاصيل. بناءً على النتائج من خلال ETc وحسابات متطلبات ري المحاصيل ، يمكن بعد ذلك جدولة الري وتحديد الفترات بين الريات. في هذا البحث تم استخدام CROPWAT 8.0 لتقييم الاحتياجات المائية ومدي تأثير التغيرات المناخية عليها وتقديم إرشادات عامة لإنتاج ثلاثة أنواع من محاصيل الموز ، الفلفل الحلو ، البطاطس ، وكلها في محافظة مطروح منطقة الدراسة الواقعة في الساحل الشمالي في مصر.

1. INTRODUCTION

Water is considered one of the most important national security issues in Egypt, past and present. Water is the biggest challenge for agriculture in Egypt, as water is one of the ex-tremely scarce resources in the region. The Nile River is the main source of water in Egypt. It is worth noting that the Nile River is the longest river in the world and serves at least 10 countries: Rwanda, Burundi, the Democratic Republic of the Congo, Tanzania, Kenya, Uganda, Ethiopia, South Sudan, Sudan, and Egypt, and there are many problems and conflicts throughout history from the difficulty of satisfying all the conflicting parties. In light of the government's endeavor to save water, the government has taken measures aimed at rationalizing the consumption of irrigation. The Ministry of Irrigation and Water Resources in Egypt is also working to launch campaigns to raise farmers' awareness of reducing water use. Crop cultivation is an important part of the Egyptian economy, to this end, improvements and developments are planned in the various irrigation systems and water management and rationalization protocols. The Water Demand Assessment (WDA) for crops is considered as the first important step to effectively and efficiently manage the production, and to maintain sustainable resources. WDA is also the most important element in water budgeting for any agricultural activity. WDA methods developed and empowered with profound technological solutions, tools and databases that make the estimation faster, easier, and more accurate. The irrigation requirement for crops in the Marsa Matrouh region were calculated and determined using CROPWAT 8.0, with the knowledge of some meteorological standards for the region. The purpose of this study is to study on irrigation water needs and the effect of climate change on water requirements and the extent of this impact on the quantities of water used to irrigate crops in Matrouh governorate located in the north coast in Egypt. The main objectives are:

- How to irrigate.
- How much to irrigate.
- When to irrigate.

This is presented in this paper under the following headlines:

- Materials and methods.
- Results and discussion.
- Conclusions and recommendations.

2. MATERIALS AND METHODS

2.1 Study Location

The study area is Marsa Matrouh in the Arab Republic of Egypt. Marsa Matrouh is a harbor on North Coast of Egypt and the capital of Matrouh Governorate. Marsa Matrouh is about 240 km from Alexandria in the west, and 222 km from the Salloum area on the main highway from the Nile. Delta to the Libyan Border and 534 km to the north and west from Cairo. This lovely city is famous for tourism .It rises 30 m above the sea level, it is known for its lagoons and white-sand beaches. It is located on a large bay, it has the resort stretching along the shore. Main activities of the population (counted 108000 people in 2005, including around 40% of the total population of Matrouh Governorate) are trade, sheep and camels grazing as well as agriculture & cultivation of crops. The people of Marsa Matrouh are Bedouins (the most common ethnic in Matrouh Governorate), Egyptian, and Egyptian-Libyans ethnics.

2.2 Crop Water Requirement

The reference evapotranspiration ET0 of individual agro-ecological units are calculated by Penman- Monteith method, using decision support software –CROPWAT 8.0.

2.3 Meteorological Data

Meteorological parameters used for calculation of ETo are latitude, longitude and altitude of the station, maximum and minimum temperature, maximum and minimum relative humidity (%), wind speed and sunshine hours which was collected. Some of the important soil characteristics that were used in this study to estimate crop water requirements are available water content (mm / m) and soil depth (cm).

2.4 Crop Data

Data and information gathered on planting and harvesting dates for each crop are placed and arranged into a crop pattern. The Crop module requires crop data over the different development stages, follow:

- Initial stage.
- Development stage.
- Mid-season stage.
- Late season stage.

2.5 Crop Evapotranspiration (ETc)

ET0 is multiplied by an empirical crop coefficient (Kc) to produce an estimate of crop evapotranspiration (ETc), as in equation (1)

$$ETc = Kc \times ETo \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

3. RESULTS AND DISCUSSION

The results obtained from the executed experimental program are presented and discussed.

3.1 Climate /ETo Data

The Reference Evapotranspiration (ETo) illustrates the poten-tial evaporation of a good irrigation herb crop. The water requirements of other crops are directly related to this cli-matic parameter. Although there are several methods for determining ETo, the Penman-Monteith methodhas been recommended as the method of suitable combination to calculat ETo from climatic data on:

- Temperature.
- Humidity.
- Sunshine.
- Wind speed are shown in **Table 1**.

Table1. Average monthly climate data in Marsa Matrouh

attitude 31.33 N			Longitude E		Altitude 30.0 m	
Month	Min Temp (C°)	Max Temp (C°)	Humidity (%)	Wind (m/s)	Sun (hr)	ET ° (mm/d)
Jan	8.7	17.7	84	5.2	4.6	1.83
Feb	8.9	18.5	82	5.3	6.0	2.27
Mar	10..4	19.6	85	5.2	7.4	2.64
Apr	12.5	22.9	84	5.3	8.7	3.52
May	15.1	25.3	84	4.5	9.3	4.11
June	18.6	28.1	86	4.6	9.7	4.51
July	20.7	28.6	91	4.4	10.0	4.34
Aug	21.2	29.5	89	4.0	9.5	4.37
Sep	19.9	28.5	90	4.0	8.1	3.56
Oct	17.2	26.5	92	3.9	6.2	5.52
Nov	13.5	22.8	98	4.1	4.5	1.39
Dec	10.4	19.3	93	5.0	5.1	1.37
Average	14.8	23.9	88	4.6	7.4	3.04

3.2 Rainfall Data

Average monthly rainfall: The computed mean of a series of precipitation records to be used in computing CWR is to represent average climatic conditions.

Effective rainfall: It is the part of the rainfall used from the cultivated crop effectively after precipitation losses due to runoff, which is taken into account when calculating the irrigation requirements of the crops. USDA S.C. method was used in the calculation effective rainfall as shown in **Table 2**. Although the amount of rainfall average in Marsa Matrouh is estimated to be approximately 120 mm annually (values varies in different references from 100 mm per annum to around 150 mm per annum), and regarded to be among the highest in Egypt, but it is still regarded to be less than the international average by approximately 55% (the international averages start from 250 mm per annum). The phenomenon of varying rainfall is one of the main obstacles experienced by arid and semi-arid areas because of its bad effects on rain-fed agriculture. As the region lies in the semi-arid climate zone, agriculture depends on rainwater and groundwater, so winter is the most important planting season.

Table2. Rain amount data in Marsa Matrouh

attitude 31.33 N			Longitude E		Altitude 30.0 m	
Month	Min Temp (C°)	Max Temp (C°)	Humidity (%)	Wind (m/s)	Sun (hr)	ET ° (mm/d)
Jan	8.7	17.7	84	5.2	4.6	1.83
Feb	8.9	18.5	82	5.3	6.0	2.27
Mar	10..4	19.6	85	5.2	7.4	2.64
Apr	12.5	22.9	84	5.3	8.7	3.52
May	15.1	25.3	84	4.5	9.3	4.11
June	18.6	28.1	86	4.6	9.7	4.51
July	20.7	28.6	91	4.4	10.0	4.34
Aug	21.2	29.5	89	4.0	9.5	4.37
Sep	19.9	28.5	90	4.0	8.1	3.56
Oct	17.2	26.5	92	3.9	6.2	5.52
Nov	13.5	22.8	98	4.1	4.5	1.39
Dec	10.4	19.3	93	5.0	5.1	1.37
Average	14.8	23.9	88	4.6	7.4	3.04

The results showed the annual reference evapotranspiration (ETo) was estimated at 1109.6 mm. The lowest daily value of ETo of 1.37 mm, was observed in December month, while the highest value 4.51 mm was observed in June.

From the study of **Fig** (1- 4), It is notes the following factors play an effective role in irrigation water needs:

- One of the important factors in the process of soil moisture occurrence is rainfall, as this process plays a major role in increasing crop productivity.
- Wind affects the motion of air currents. It also impacts the composition of air humidity/moisture, plant transpiration and Soil cooling process.
- Solar radiation directly affects agricultural crops, as it may cause fire to some crops. It is also an important and essential factor as it directly affects air temperature, soil, humidity and winds.
- Humidity/moisture is also an important factor, which is influenced by temperature, soil cover, wind, etc.

Fig .1 **-** Temperature variations in Marsa Matrouh

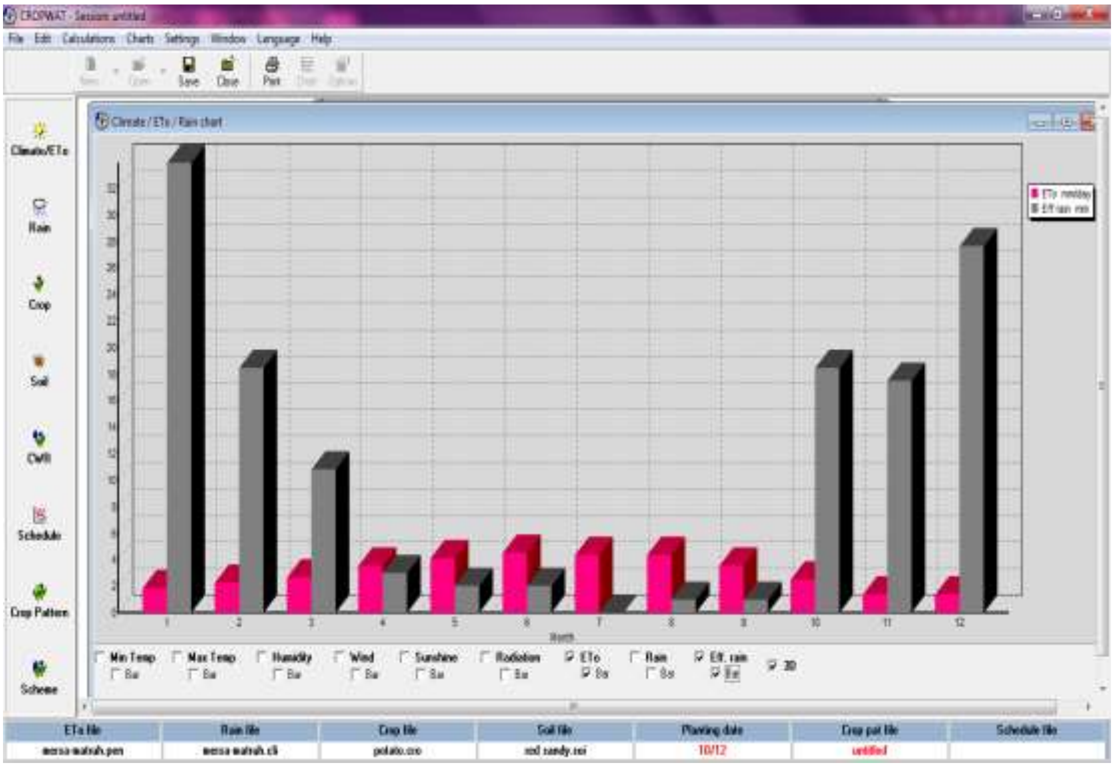


Fig. 2 **-** Variation of rainfall with ETo in Marsa Matrouh

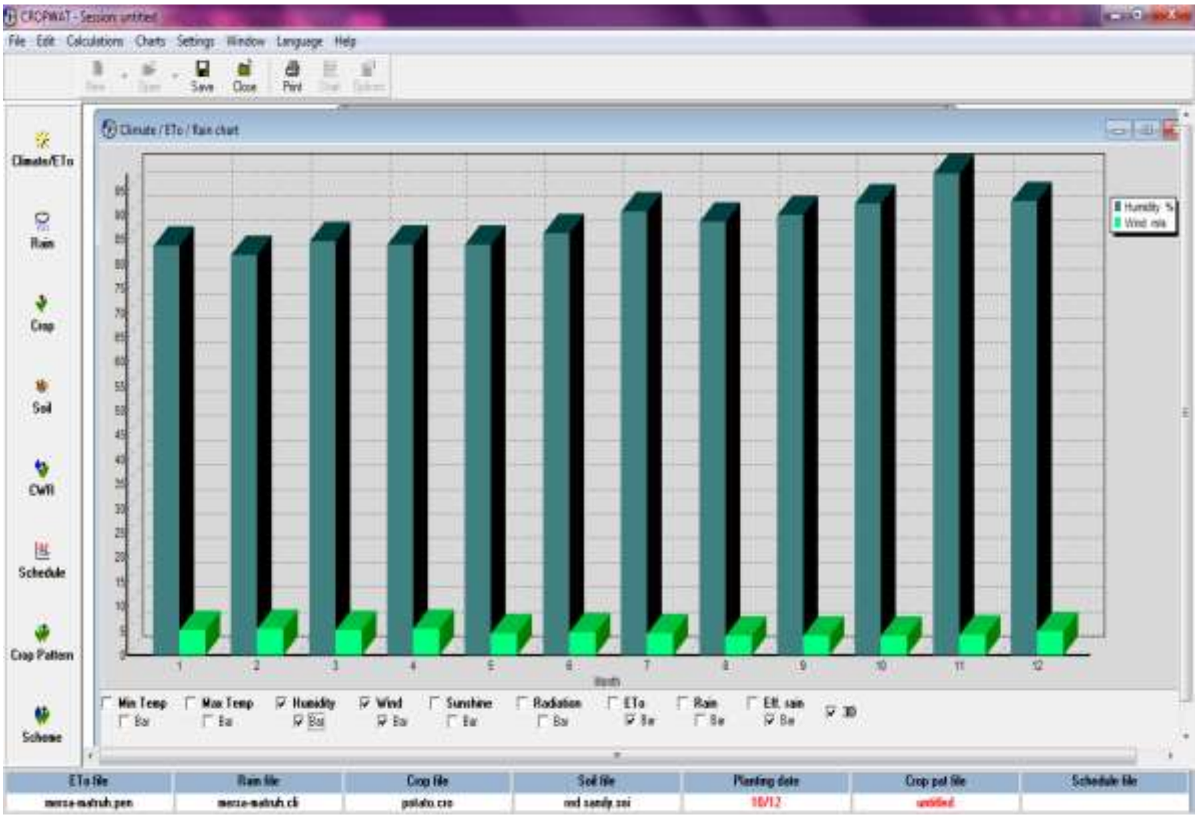


Fig. 3 - Relation between wind speed and humidity among the months of the year in Marsa Matrouh

Fig. 4 - Sun hours & average radiation over the seasons in Marsa Matrouh

3.3 Crop factor (K_c) and phenological periods

The planting date was set in the program to fit the actual planting date, implemented in the experiments, and the harvest date was left to be calculated by the program on the basis of length of phenological periods The depth of effective roots was also chosen for the data according to the effective root depth calculated in advance for research experiments, as this value is included in the calculation of the amount of irrigation water and net water consumption. The program needs crop factor values for three main growth stages, which are the stage primary, mid-season and harvest stages in order to be able to calculate the crop factor in its development stage and the end crop stage, as shown in the figures from 5 to 7.

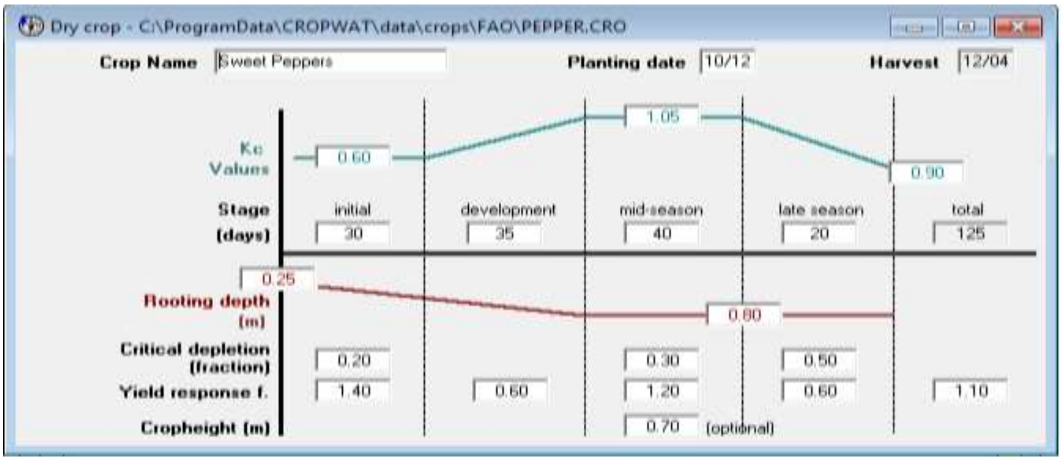


Fig. 5 - Crop factor and phonological periods for sweet pepper

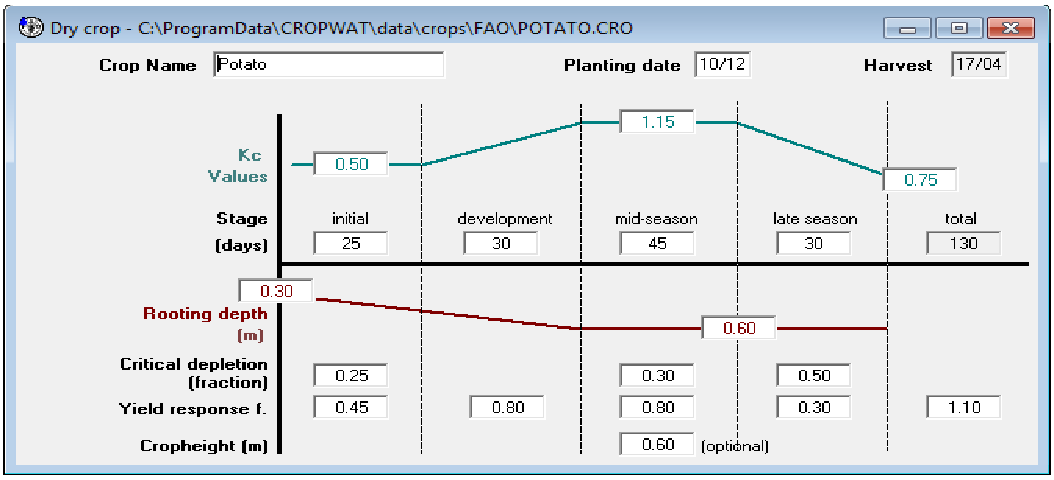


Fig .6 - Crop factor and phonological periods for potato

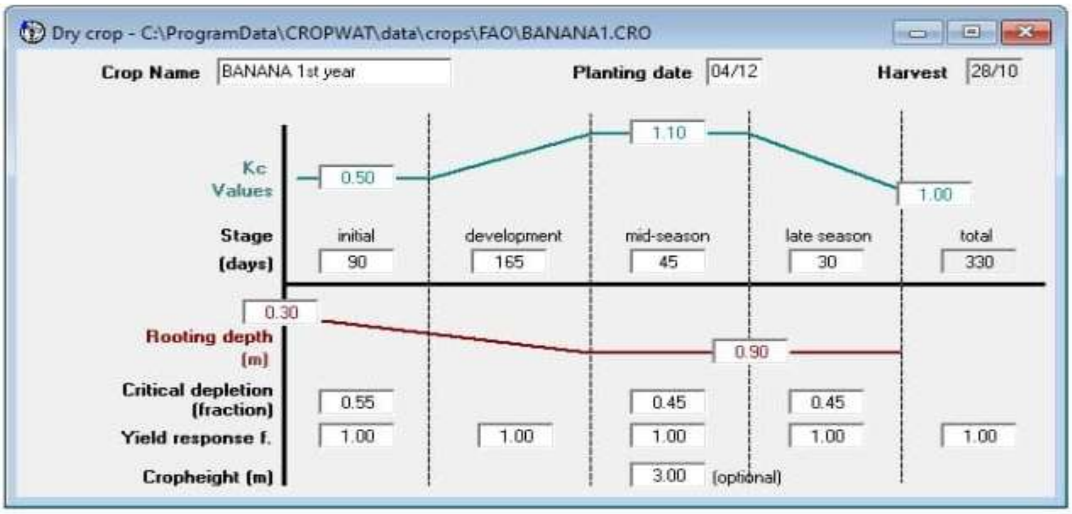


Fig. 7- Crop factor and phonological periods for banana

3.4 The soil characteristics

The soil parameters important for irrigation scheduling. Sediments carried by flooding rainfalls form the soil of Marsa Matrouh because Marsa Matrouh is a coastal city. According to the researches, have been done in preparing this paper Marsa Matrouh soil is defined as "Red Sandy" soil. Figure 8 shows some of the soil characteristics Hydro physical at the study site. An estimate of the surface runoff for the effective rain calculation will be allowed by maximum rain infiltration rate. This is rain intensity function, soil type and slope class.

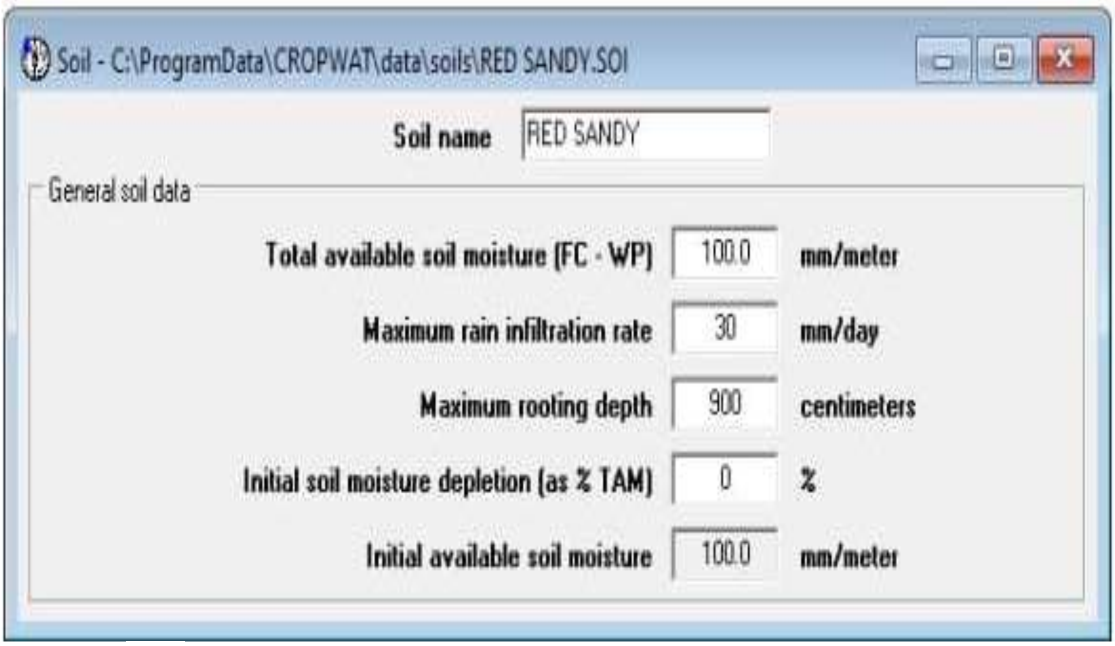


Fig. 8 - Soil characteristics Hydro physical in Marsa Matrouh

Figure 9 below, shows the soil water retention in mm com-pared with the period of time after plant (in days). As seen in the figure, we can notice the increase of the soil water retention average after plant to get saturation in average of 60 days, after which it stays almost within the same level.

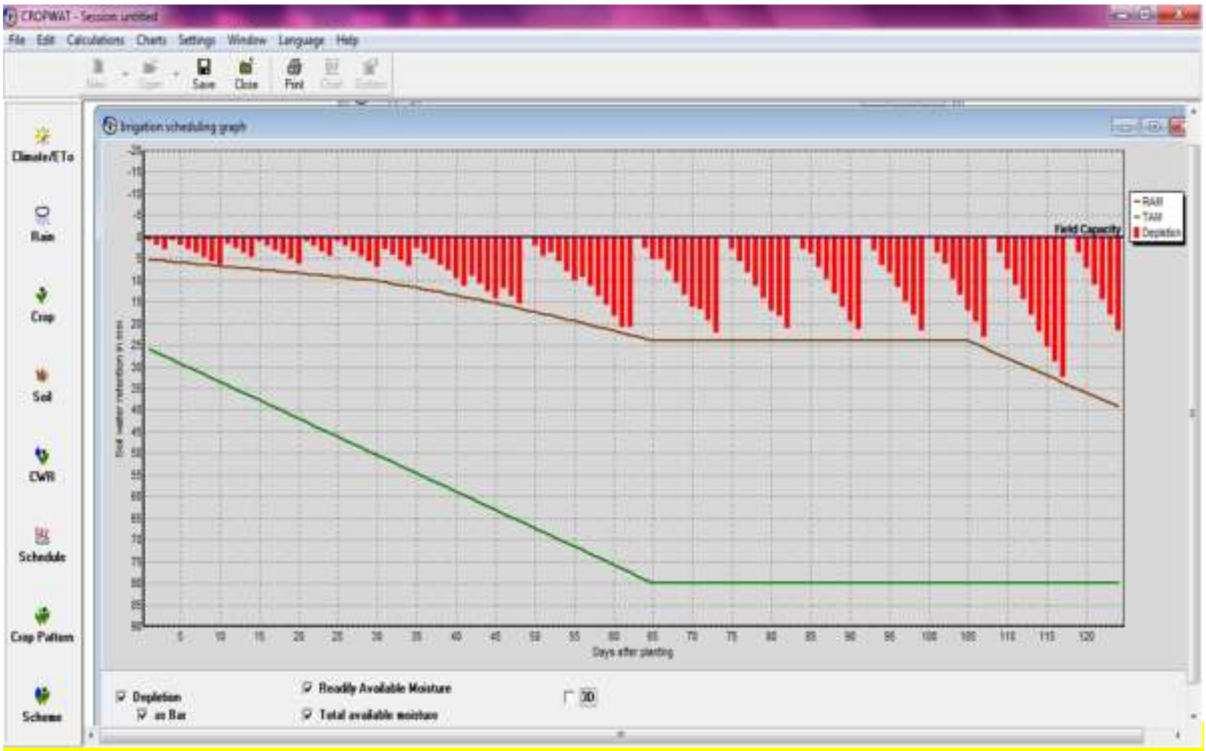


Fig. 9 - Soil Water Retention (in mm) vs. time (in days), in Marsa Matrouh as visualized

3.5 Crop Water Requirements

The water requirements for each crops selected, which is one of the most main outputs of CROPWAT 8.0, is seen in detailed tables for each crop as shown below (fig 10 to fig 12).

3.6 Scheduling and Scheme

Scheduling shows the proposed crop irrigation schedule that CROPWAT 8.0 presents based on the data fed to the pro-gram, and the expertise built into the system. The figure 19 below shows the schedule proposed by CORPWAT 8.0. Scheme Supply shows the details and values should be regarded for irrigation the crops, as seen in figure 13 and **T**able 3 below.

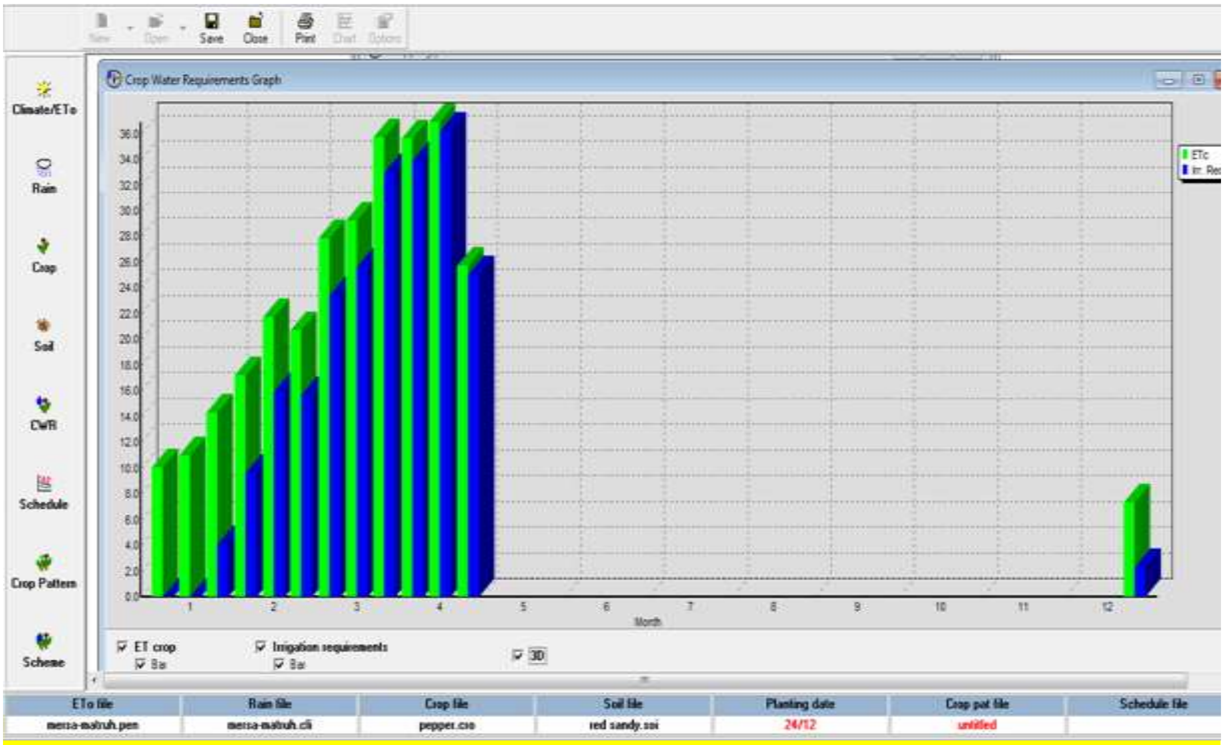


Fig. 10 - Variation irrigation requirements with ET_o

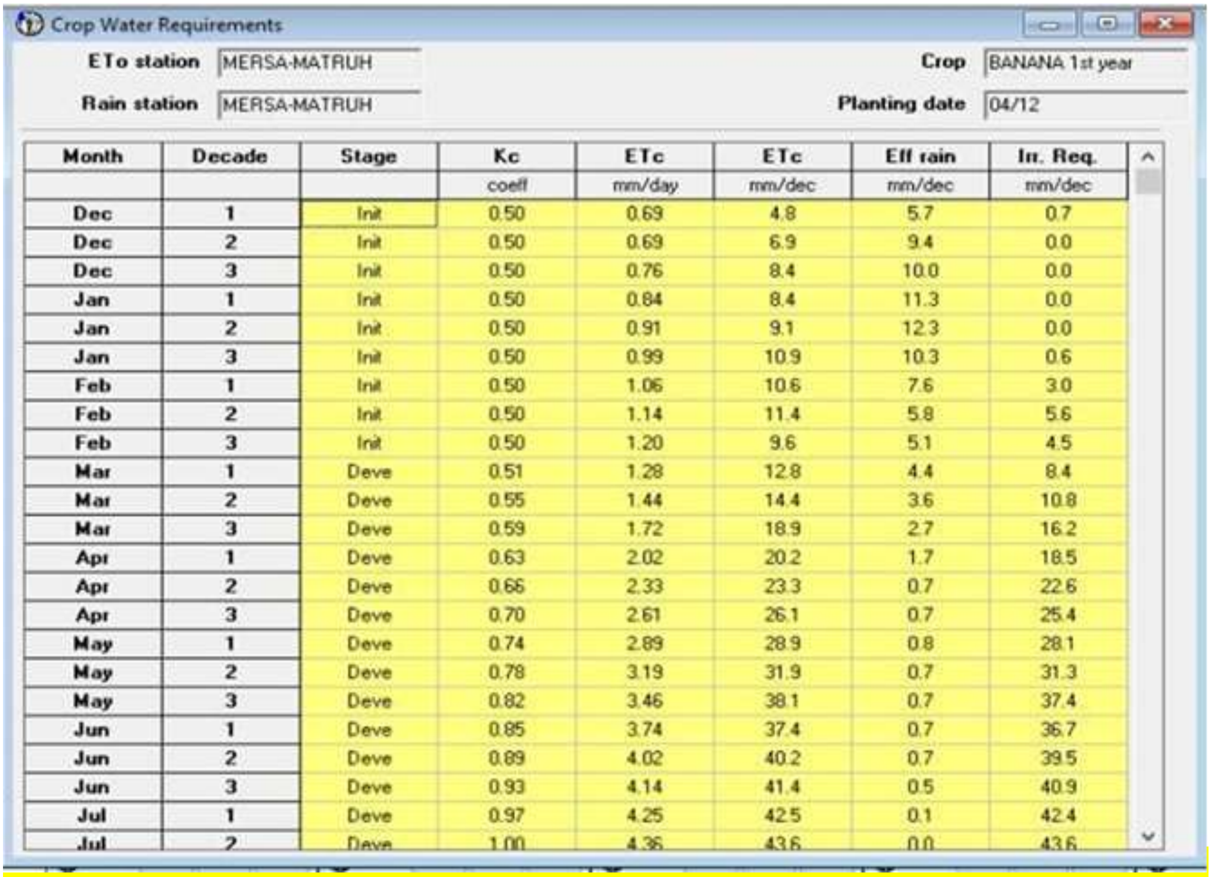
Crop Water Requirements

ETo station: MERSA-MATRUH | Crop: Potato

Rain station: MERSA-MATRUH | Planting date: 10/12

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	1	Init	0.50	0.69	0.7	0.8	0.7
Dec	2	Init	0.50	0.69	6.9	9.4	0.0
Dec	3	Init	0.50	0.76	8.4	10.0	0.0
Jan	1	Deve	0.57	0.95	9.5	11.3	0.0
Jan	2	Deve	0.79	1.45	14.5	12.3	2.2
Jan	3	Deve	1.04	2.06	22.7	10.3	12.4
Feb	1	Mid	1.21	2.56	25.6	7.6	18.0
Feb	2	Mid	1.21	2.75	27.5	5.8	21.7
Feb	3	Mid	1.21	2.89	23.1	5.1	18.1
Mar	1	Mid	1.21	3.04	30.4	4.4	25.9
Mar	2	Late	1.21	3.18	31.8	3.6	28.2
Mar	3	Late	1.11	3.27	35.9	2.7	33.2
Apr	1	Late	0.98	3.15	31.5	1.7	29.8
Apr	2	Late	0.86	3.01	24.1	0.6	23.4
					292.6	85.5	213.6

Fig. 11- Water requirements for potato crop

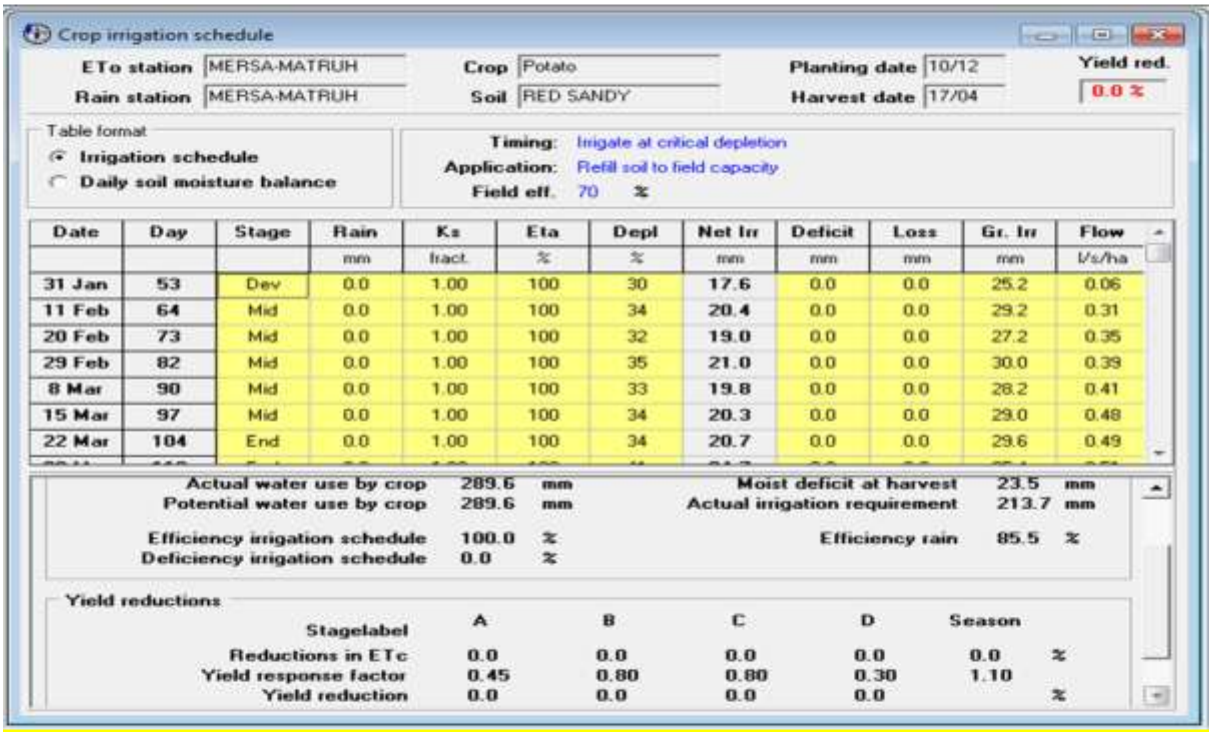


Crop Water Requirements

ETo station MERSA-MATRUH | Crop BANANA 1st year
Rain station MERSA-MATRUH | Planting date 04/12

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	1	Init	0.50	0.69	4.8	5.7	0.7
Dec	2	Init	0.50	0.69	6.9	9.4	0.0
Dec	3	Init	0.50	0.76	8.4	10.0	0.0
Jan	1	Init	0.50	0.84	8.4	11.3	0.0
Jan	2	Init	0.50	0.91	9.1	12.3	0.0
Jan	3	Init	0.50	0.99	10.9	10.3	0.6
Feb	1	Init	0.50	1.06	10.6	7.6	3.0
Feb	2	Init	0.50	1.14	11.4	5.8	5.6
Feb	3	Init	0.50	1.20	9.6	5.1	4.5
Mar	1	Deve	0.51	1.28	12.8	4.4	8.4
Mar	2	Deve	0.55	1.44	14.4	3.6	10.8
Mar	3	Deve	0.59	1.72	18.9	2.7	16.2
Apr	1	Deve	0.63	2.02	20.2	1.7	18.5
Apr	2	Deve	0.66	2.33	23.3	0.7	22.6
Apr	3	Deve	0.70	2.61	26.1	0.7	25.4
May	1	Deve	0.74	2.89	28.9	0.8	28.1
May	2	Deve	0.78	3.19	31.9	0.7	31.3
May	3	Deve	0.82	3.46	38.1	0.7	37.4
Jun	1	Deve	0.85	3.74	37.4	0.7	36.7
Jun	2	Deve	0.89	4.02	40.2	0.7	39.5
Jun	3	Deve	0.93	4.14	41.4	0.5	40.9
Jul	1	Deve	0.97	4.25	42.5	0.1	42.4
Jul	2	Deve	1.00	4.36	43.6	0.0	43.6

Fig. 12 - Water requirements for banana crop



Crop irrigation schedule

ETo station MERSA-MATRUH | Crop Potato | Planting date 10/12 | Yield red.
Rain station MERSA-MATRUH | Soil RED SANDY | Harvest date 17/04 | 0.0 %

Table format
- Irrigation schedule
- Daily soil moisture balance

Timing: Irrigate at critical depletion
Application: Refill soil to field capacity
Field eff. 70 %

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
31 Jan	53	Dev	0.0	1.00	100	30	17.6	0.0	0.0	25.2	0.06
11 Feb	64	Mid	0.0	1.00	100	34	20.4	0.0	0.0	29.2	0.31
20 Feb	73	Mid	0.0	1.00	100	32	19.0	0.0	0.0	27.2	0.35
29 Feb	82	Mid	0.0	1.00	100	35	21.0	0.0	0.0	30.0	0.39
8 Mar	90	Mid	0.0	1.00	100	33	19.8	0.0	0.0	28.2	0.41
15 Mar	97	Mid	0.0	1.00	100	34	20.3	0.0	0.0	29.0	0.48
22 Mar	104	End	0.0	1.00	100	34	20.7	0.0	0.0	29.6	0.49

Actual water use by crop 289.6 mm | Moist deficit at harvest 23.5 mm
Potential water use by crop 289.6 mm | Actual irrigation requirement 213.7 mm

Efficiency irrigation schedule 100.0 % | Efficiency rain 85.5 %
Deficiency irrigation schedule 0.0 %

Yield reductions

Stagelabel	A	B	C	D	Season	
Reductions in ETc	0.0	0.0	0.0	0.0	0.0	%
Yield response factor	0.45	0.80	0.80	0.30	1.10	
Yield reduction	0.0	0.0	0.0	0.0		%

Fig. 13 - Scheduling details for potato crop as indicated by CROPWAT 8.0

Table 3.Proposed scheme for the three selected crops

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Perception deficit												
Banana	0.6	13.1	35.4	66.5	96.8	117.1	136	145.6	117.5	60.1	0.0	0.7
Potato	20.3	57.8	80.8	32.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
Sweet pepper	127	51.2	80.2	20.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18
Net Scheme irr. req in mm/day	0.3	1.4	2.0	1.4	1.2	1.6	1.8	1.9	1.6	0.8	0.0	0.0
in mm/month	10.1	37.9	63.4	42.6	38.7	46.9	54.4	58.3	47.0	24.0	0.0	0.0
in l/s/h	.04	0.16	0.24	0.16	0.14	0.18	0.20	0.22	0.18	0.0	0.0	0.0
Irrigated area (% of total area)	100	100	100	100	40	40	40	40	40	40	0.0	100
irr. req for actual area (l/s/h)	0.04	0.16	0.24	0.16	0.36	0.45	0.51	0.54	0.45	0.22	0.0	0.0

Based on these results through ETc crop evaporation and crop irrigation requirement calculations, irrigation projects can then be scheduled for different seasons for water use efficiency. I think this study is helpful in achieving the goal, how to irrigate, how much to irrigate, and when to irrigate.

4. CONCLUSION & RECOMMENDATIONS

From the previous analysis of the obtained results, the conclusions which have been reached are as follow:

- The problem with irrigation is that it consumes so much water if not properly managed so hopefully with the calculations of (CWR) to develop irrigation schedules under various management conditions.
- To combat water poverty, it is necessary to choose crops that are easily adapted to climatic conditions.
- A water-climate balance has been established Using evapotranspiration (ET_o) and effective rainfall.
- One of the factors that affect the increase in evapotranspiration (ET_o) and thus the irrigation needs is temperature, as it has a great direct impact on plants.
- The net irrigation demand, the gross irrigation demand and irrigation interval for the various crops grown have been computed.
- Estimating crop water requirements helps maintain water balance.
- Determining the quantities of water used for irrigation helps to avoid damages of excess or shortage of water.
- Irrigation scheduling contributes to identifying the water consumption of crops and thus making full use of the cultivated areas.

- Good irrigation management plays a big role in increasing productivity.
- From the analysis of the obtained results, it was noticed in terms of the number of irrigations that there was a high matching between the estimated and real values for banana and potato, but for sweet pepper there was a difference in irrigations, this difference is due to the difference in crop coefficient values between the estimated program value and the calculated (real value).
- Among the factors that help in saving water for irrigation is the use of rainfall, so it is important to know when to plant crops.
- This study is helpful in determine how to irrigate, how much to irrigate, and when to irrigate.
- Regional and local authorities are encouraged to spread & motivate using these programs among the targeted populations, with focus on the farmers. Special training courses should be conducted, and efforts should be made to make required hardware and software available for the poorest people to get the benefits of such systems.
- It is recommended also to make these applications available in Arabic, as they are already available in English, French, Russian, and Spanish.

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