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Evaluating water demand and scheduling irrigation for some agricultural crops in Siwa

By

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الملخص العربى:

يعتبر معرفة الاحتياجات المائية للمحاصيل الزراعية الخطوة الأولى المهمة في الأنشطة الزراعية والري الناجحة و مطلوب لكلا المستويين: المستوى الفردي والتخطيط الاستراتيجي للتنمية المستدامة للمجتمعات,و تزداد الحاجة لمعرفة الاحتياجات المائية للمحاصيل لأن قضية تغير المناخ تعقدت ، وفي الحالات التي يعمل فيها الناس في الزراعة والري لا يتبعون المعايير وأفضل الممارسات المطلوبة للزراعة والري المستدامين ، كما هو الحال في البلدان النامية والمنطقة العربية لذلك يعد استخدام CROPWAT 8.0 و CLIMWAT 2.0 مفيدا وواعدا لزيادة الإنتاجية والحفاظ على الموارد ومن ثم تطوير هذه التطبيقات في إطار منظمة الأغذية والزراعة للأمم المتحدة (الفاو) , وتتميز هذه التطبيقات بأنها سهلة الاستخدام ومجهزة بمعايير الخبرة والإرشادات. أجريت هذه الدراسة بهدف دراسة مدي ملائمة برنامج CROPWAT 8.0 في حساب الاحتياجات المائية وجدولة الري لأربعة محاصيل: القمح الربيعي ، البطاطس ، العنب ، والذرة في واحة سيوة و الواقعة في مصر على بعد حوالي 50 كم من الحدود الشرقية من ليبيا وذلك باستخدام بيانات تجارب حقلية منفذة مسبقا في محطة بحوث الري للمنطقة.

Abstract:

Water Demand Assessment (WDA) is considered the first important step in successful agricultural and irrigation activities. It is required for both levels: the individual level and sustainable development strategic planning for the communities. The need for WDA is increased as the climate change issue has been complicating, and in situations where people work in agriculture and irrigation are not following the standards and best practices required for sustainable agriculture and irrigation, like in developing countries and the Arab region. Using CROPWAT 8.0 for WINDOWS and CLIMWAT 2.0 for CROPWAT is helpful and promising to increase productivity and maintain the resources. These applications are developed under the Food and Agriculture Organization of the United Nations (FAO). They are featured with a friendly environment, easy to use, equipped with expertise standards and guidance, and they are available for download and installation for free. In this paper, the author has the experience to use CROPWAT 8.0 and CLIMWAT 2.0 to assess the water needs for four crops: spring wheat, potatoes, table grape, and maize in SIWA Oasis, located in Egypt

about 50 Km to the eastern borders of Libya. The main aim is to explore and develop the experience of using these two programs. A straightforward methodology has been in place, started with installing CROPWAT 8.0 and CLIMWAT 2.0 for CROPWAT; defining and researching on the selected area (SIWA); selection of the location (SIWA) in CLIMWAT 2.0; initializing, visualizing and reviewing the relevant data displayed by CROPWAT 8.0; and receiving and analyzing the results through the programs running; data visualization. These programs have been accurate in concluding the values, recommendations, and guidance regarding producing the selected crops. The simplicity, easy to use, and user-friendly environment have all been noticed. The author recommendations include encouraging the use of these programs at large scales; performing specialized and simple courses on these programs for the targeted people; securing the required hardware and software to facilitate the use of these programs through several computer labs opened for the targeted people and making strategic partnerships with local and international Non-Governmental Organizations (NGOs) and corporate social responsibilities programs (CSR) for that purpose.
Index Terms: Agriculture, Irrigation, Irrigation Management, CORPWAT 8.0 for WINDOWS, CLIMWAT 2.0 for CORPWAT, SIWA, Productivity, Sustainability and Water Resources Management.

Introudation

Agriculture is one of the top essential and prior economic activities in Egypt. Climate change, water scarcity, decreasing of productivity while increasing in the demands of agricultural products (due to changing lifestyle and increased population), the relative availability of the water (regardless of the water crisis that is taking place), and the need to improve the practice of agriculture and irrigation management to increase the efficiency and effectiveness of the crops; all have been highlighting the importance of utilizing smart and technological tools in order to achieve better quality in crops and irrigation while sustaining the resources, especially when the farmers lack the best practice and standards and contribute to wasting water. It is estimated that the average amount of water used to irrigate 1 hectare in the Arab region is around 12000 cubic meters annually. In contrast, the actual required amount of water should not exceed 7500 cubic meters. This has led to water waste, decreased soil quality, and increased salts within it.

The Water Demand Assessment (WDA) for crops is considered the first important step to effectively and efficiently manage the production and maintain sustainable resources. WDA is also the most crucial element in water budgeting for any agricultural activity. WDA methods have been developing and empowered with profound technological solutions, tools, and databases that make the estimation faster, easier, and more accurate. CROPWAT 8.0 for WINDOWS and CLIMWAT 2.0 for CROPWAT are two useful programs to manage agricultural and irrigation management, made by the Food and Agriculture Organization of United Nations (FAO), and distributed free of charge.

After fed with the required data, CROPWAT 8.0 for Windows can calculate crop water demand and irrigation requirements depending on soil, climate and crop data. The program also helps in creating irrigation schedules according to working conditions and calculates various schemes to improve work performance. CROPWAT 8.0 can evaluate and develop farmers' irrigation practices and evaluate crop performance to increase crop yield efficiency. The development of irrigation schedules and plans in CROPWAT 8.0 is based on daily soil and water balance using a variety of water supply options and the irrigation management files created.The program's climate data are based on monthly temperature, rainfall/precipitation, wind speed, solar radiation and air humidity/moisture. CROPWAT 8.0 is empowered with a data visualization engine to produce graphs and charts for better and faster data presentations and decision-making.

In this paper, the author briefed her experience using CROPWAT 8.0 and CLIMWAT to assess the water needs and provide general guidance to produce four kinds of crops: spring wheat, potatoes, table grape, and maize, all in SIWA Oasis.

The main objective is to introduce and experience using of CROPWAT 8.0 and CLIMAWT as powerful tools in agriculture and irrigation management.

Methodology

CROPWAT 8.0 for WINDOWS and CLIMWAT 2.0 for CROPWAT are two important computer programs (applications) used to estimate and provide a guiding framework for crops and irrigation management. These two powerful, user-friendly, and simple-to-use applications, developed under the Food and Agriculture Organization of the United Nations (FAO), are connected to a global database of essential data required to make the estimation guide the agricultural and irrigation activities.

CLIMWAT 2.0 for CROPWAT is a database used with CROPWAT. It can compute crop water requirements, irrigation supply, and help develop irrigation plans for different locations globally. CLIMWAT 2.0 provides monitored data on agriculture and climate for more than 5000 locations worldwide. CLIMWAT provides per-month-basis long-term means of seven climate parameters, specifically: daily max temperature in °C, daily min temperature in °C, relative humidity in %, wind speed in km/day, daily sunshine hours, solar radiation in MJ/m2/day, rainfall amount in mm/month, sufficient rainfall in mm/month, reference evapotranspiration using the Penman-Monteith method in mm/day. The data can be collected from any number of stations in the format suitable for their use in CROPWAT. The system makes two files for each selected location. One is for long-term rainfall data per month [mm/month]. The second file calculates long-term monthly averages for the seven parameters mentioned. Coordinates and the elevation of the station selected are also included.

Definition and Researches

First, the subject area (SIWA) was defined and researched to have the required information necessary to feed the applications. SIWA (also known as SIWA Oasis) is an isolated oasis located in the Western Desert in Egypt 50 Km east of the Libyan Border and 560 Km from Cairo. Its name, SIWA, means "The Field of Tree" in the ancient language. Around 33,000 people live in SIWA. Most of them are Berbers, who speak a unique dialect known as (Siwi) and the Egyptian Arabic dialect. SIWA has a profound cultural, historical, and tourist importance. It was a part of ancient Egypt, where it was called the Oasis of Amun Ra.

SIWA is located in a deep depression about -19 meters below the sea level near Qattara depression, which is also below sea level. Like the rest of Egypt, the SIWA climate is a hot desert. The Taple 1 below provides more details about the climate of SIWA. Agriculture is the main activity in SIWA. The most important crops are dates and olives. It has been estimated that there are around 280,000 date palms generating around 25,000 tons of dates annually and corresponding to approximately 2% of Egypt's total dates production. SIWA also produces around 27,000 tons of olives each year. Other crops include vegetables like molukia, fruits like tomatoes and grapes, karkade, and medicinal agriculture. Date palms are cultivated in extensive gardens and are usually intercropped with fruits, vegetables, and cereals. Siwan farmers are considered to have rich knowledge and experience in growing, pollination, maintaining, harvesting, and post-harvesting palm trees.

Taple 1. Claimate in SIWA over 12 months

Climate data for Siwa [hide]													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C (°F)	29.3 (84.7)	34.6 (94.3)	41.6 (106.9)	44.8 (112.6)	48.0 (118.4)	48.2 (118.8)	45.2 (113.4)	46.2 (115.2)	42.8 (109.0)	41.9 (107.4)	37.5 (99.5)	29.0 (84.2)	48.2 (118.8)
Average high °C (°F)	19.3 (66.7)	21.5 (70.7)	24.5 (76.1)	29.9 (85.8)	34.0 (93.2)	37.5 (99.5)	37.5 (99.5)	37.0 (98.6)	34.6 (94.3)	30.5 (86.9)	25.0 (77.0)	20.5 (68.9)	29.3 (84.7)
Daily mean °C (°F)	12.1 (53.8)	14.0 (57.2)	17.3 (63.1)	21.9 (71.4)	25.8 (78.4)	29.2 (84.6)	29.9 (85.8)	29.4 (84.9)	27.1 (80.8)	22.8 (73.0)	17.3 (63.1)	13.2 (55.8)	21.7 (71.1)
Average low °C (°F)	5.6 (42.1)	7.1 (44.8)	10.1 (50.2)	13.7 (56.7)	17.8 (64.0)	20.4 (68.7)	21.7 (71.1)	21.4 (70.5)	19.5 (67.1)	15.5 (59.9)	10.2 (50.4)	6.5 (43.7)	14.1 (57.4)
Record low °C (°F)	−2.2 (28.0)	−1.3 (29.7)	0.3 (32.5)	5.7 (42.3)	7.5 (45.5)	14.0 (57.2)	17.5 (63.5)	15.9 (60.6)	11.7 (53.1)	7.8 (46.0)	2.9 (37.2)	−0.7 (30.7)	−2.2 (28.0)
Average precipitation mm (inches)	2 (0.1)	1 (0.0)	2 (0.1)	1 (0.0)	1 (0.0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	2 (0.1)	1 (0.0)	9 (0.4)
Average precipitation days (≥ 1.0 mm)	0.3	0.1	0.1	0.2	0	0	0	0	0	0	0.1	0.2	1.0
Average relative humidity (%)	56	50	46	38	34	33	37	41	44	50	56	59	45.3
Mean monthly sunshine hours	230.7	248.4	270.3	289.2	318.8	338.4	353.5	363.0	315.6	294.0	265.5	252.8	3,540.2
Source 1: NOAA[23]													
Source 2: *Climate Charts*[24]													

Installation of the Applications

CROPWAT 8.0 and CLIMWAT 2.0 were installed and started. A simple configuration is required to determine the units of measurement.

Setting Location/Station

In CLIMWAT 2.0, Egypt was selected from the list of the available countries, as shown in figure 1 below.

Then, SIWA City was selected from the list of locations in CLIMWAT 2.0, as shown in the below figure 2.

By choosing the location (also known as a station in the CROPWAT 8.0), a complete file with all required data was created to be used by the CROPWAT 8.0. As seen in the figure above, a red spot indicates the SIWA location as it was selected from the list to the right.

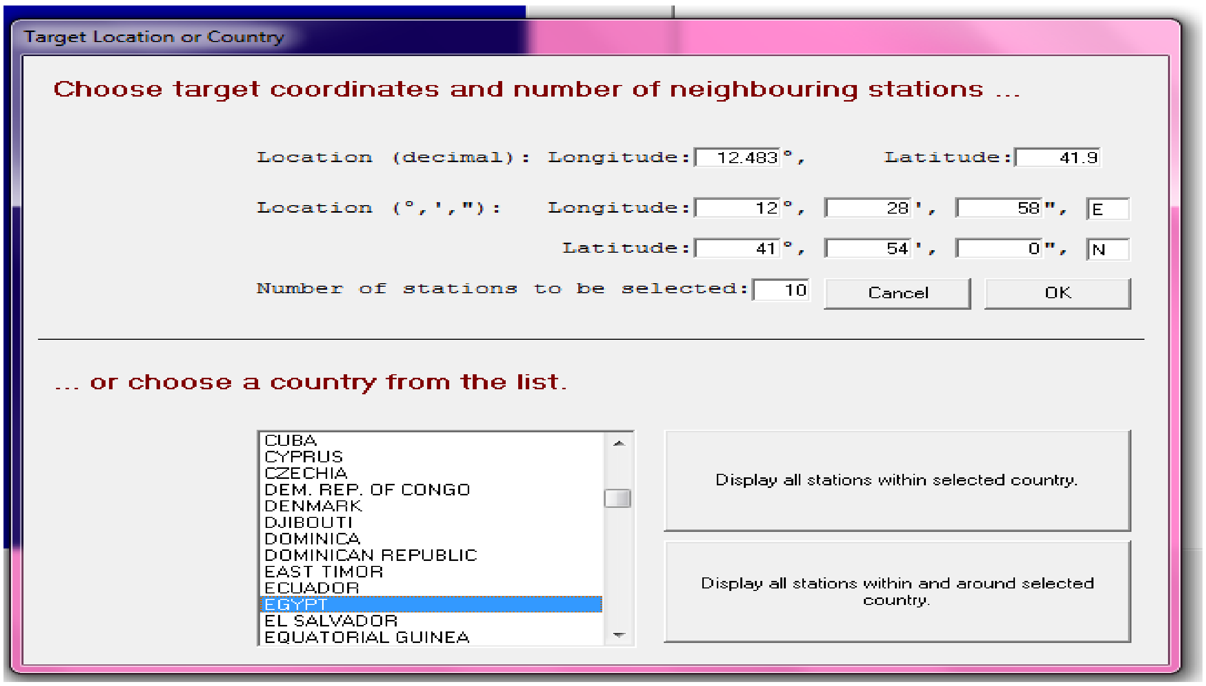
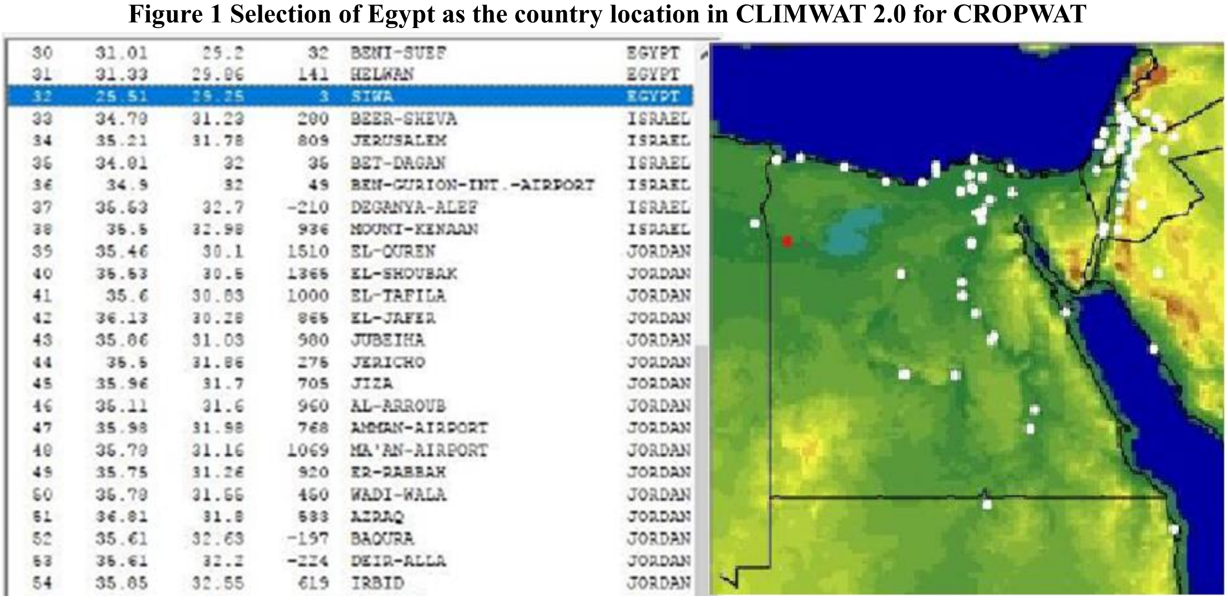


Figure 1 Selection of Egypt as the country location in CLIMWAT 2.0 for CROPWAT



30	31.01	25.2	32	BENI-SUEF	EGYPT
31	31.33	29.86	141	HELWAN	EGYPT
32	25.51	29.25	3	SIWA	EGYPT
33	34.78	31.23	280	BEER-SHEVA	ISRAEL
34	35.21	31.78	809	JERUSALEM	ISRAEL
35	34.81	32	35	BET-DAGAN	ISRAEL
36	34.9	32	49	BEN-GURION-INT.-AIRPORT	ISRAEL
37	35.63	32.7	-210	DEGANYA-ALEF	ISRAEL
38	35.5	32.98	936	MOUNT-KENAAN	ISRAEL
39	35.46	30.1	1510	EL-QUREN	JORDAN
40	35.53	30.5	1365	EL-SHOUBAK	JORDAN
41	35.6	30.83	1000	EL-TAFILA	JORDAN
42	36.13	30.28	865	EL-JAFER	JORDAN
43	35.86	31.03	980	JUBEIHA	JORDAN
44	35.5	31.86	275	JERICHO	JORDAN
45	35.96	31.7	705	JIZA	JORDAN
46	36.11	31.6	960	AL-ARROUB	JORDAN
47	35.98	31.98	768	AMMAN-AIRPORT	JORDAN
48	35.78	31.16	1069	MA'AN-AIRPORT	JORDAN
49	35.75	31.26	920	ER-RABBAH	JORDAN
50	35.78	31.56	460	WADI-WALA	JORDAN
51	36.81	31.8	533	AZRAQ	JORDAN
52	35.61	32.63	-197	BAQURA	JORDAN
53	35.61	32.2	-224	DEIR-ALLA	JORDAN
54	35.85	32.55	619	IRBID	JORDAN

Figure 2 Selection of SIWA as the defined area for the paper in CLIMWAT 2.0 for CROPWA

Initializing and Reviewing Climate /ETo Data

After choosing SIWA, it is possible to input and review all related data regarding the SIWA station by using the side panel located at the left of the CROPWAT 8.0 window. First, the climate/ETo data is initialized and reviewed, as shown next (figure 4):
As shown in the figure below (taken from CROPWAT), the average minimum temperature in SIWA is 12.6 C. The average maximum temperature is 29.9 C. The average humidity is 78%, the average wind speed is 257 Km/day, the average sun exposure is 9.1 hours per day.

Initializing and Reviewing Rain Data

By clicking on the "Rain" icon in the module bar, the rain data of the location was accessed and reviewed as shown below (figure 5):
The annual rainfall average in SIWA is estimated to be around 10 mm (values vary from 0.0 mm to around 3.0 mm).

Initializing and Reviewing Chosen Crops Data

Agriculture and corps produced depend on the region and the irrigation method used (totally rainfed agriculture, partially/assisted irrigation, or permanent irrigation). The main crops include olive, grape, palm trees, potatoes, sweet peppers, molokhia, spring wheat, etc. Some land reclamation initiatives and projects have been initiated in the region.
We can select the subject crops through the "Open" command in the menu bar in CROPWAT 8.0. When Clicking the Crop button, CROPWAT 8.0 displays the related data of the crop, as shown below (figure 6), where the table grapes crop is displayed:

Monthly ETo Penman-Monteith - C:\Program Files (x86)\CLIMWAT 2.0 for CROPWAT V2.0\SI...

Country: Location 32 — Station: SIWA

Altitude: 3 m. — Latitude: 29.25 °N — Longitude: 25.51 °E

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	m/s	hours	MJ/m²/day	mm/day
January	3.9	19.4	95	2.9	7.2	13.0	1.61
February	5.0	21.7	85	2.6	7.8	15.9	2.40
March	7.8	25.0	81	3.6	8.6	19.5	3.52
April	11.7	30.0	71	3.8	9.0	22.3	5.18
May	16.1	34.4	66	3.5	9.6	24.3	6.41
June	18.9	37.8	63	3.3	11.1	26.7	7.50
July	20.5	38.3	65	3.2	11.2	26.7	7.49
August	20.0	37.8	67	2.9	11.0	25.5	6.90
September	17.8	35.0	70	2.5	9.9	22.0	5.52
October	14.4	32.2	80	2.5	9.1	18.1	4.09
November	10.0	26.7	90	2.4	7.5	13.8	2.52
December	5.0	21.1	98	2.5	7.3	12.3	1.58
Average	**12.6**	**29.9**	**78**	**3.0**	**9.1**	**20.0**	**4.56**

Figure 4 Receiving and Reviewing Climate / ETo data of SIWA in CROPWAT 8.0

Monthly rain - C:\Program Files (x86)\CLIMWAT 2.0 for CROPWAT V2.0\SIWA.cli

Station: SIWA — Eff. rain method: USDA S.C. Method

	Rain	Eff rain
	mm	mm
January	1.0	1.0
February	1.0	1.0
March	1.0	1.0
April	1.0	1.0
May	2.0	2.0
June	0.0	0.0
July	0.0	0.0
August	0.0	0.0
September	0.0	0.0
October	0.0	0.0
November	1.0	1.0
December	3.0	3.0
Total	**10.0**	**10.0**

Figure 5 Rain amount in SIWA (CROPWAT 8.0)

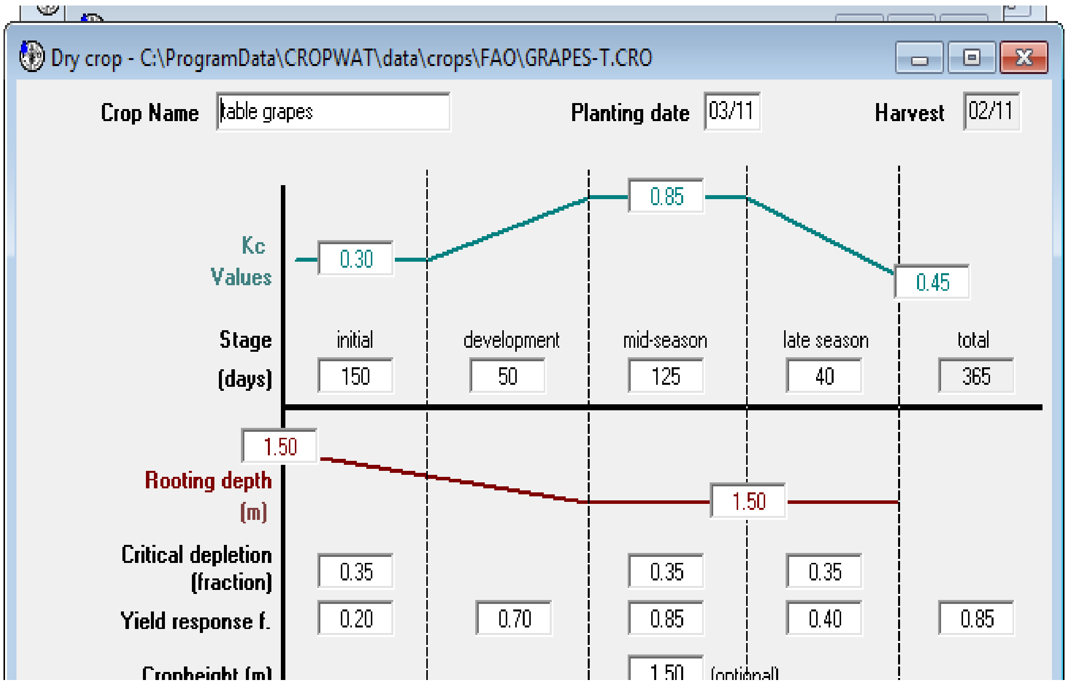


Figure 6 Table grapes crop data (CROPWAT 8.0)

In figure 7 below, the potato crop window is displayed:

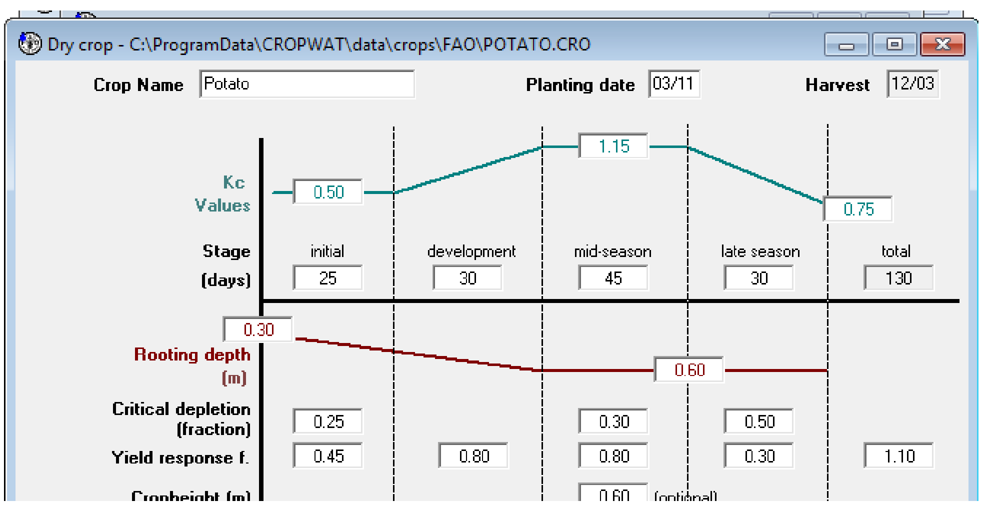


Figure 7 Potato crop data (CROPWAT 8.0)

Below in figure 8, the spring wheat crop window is displayed:

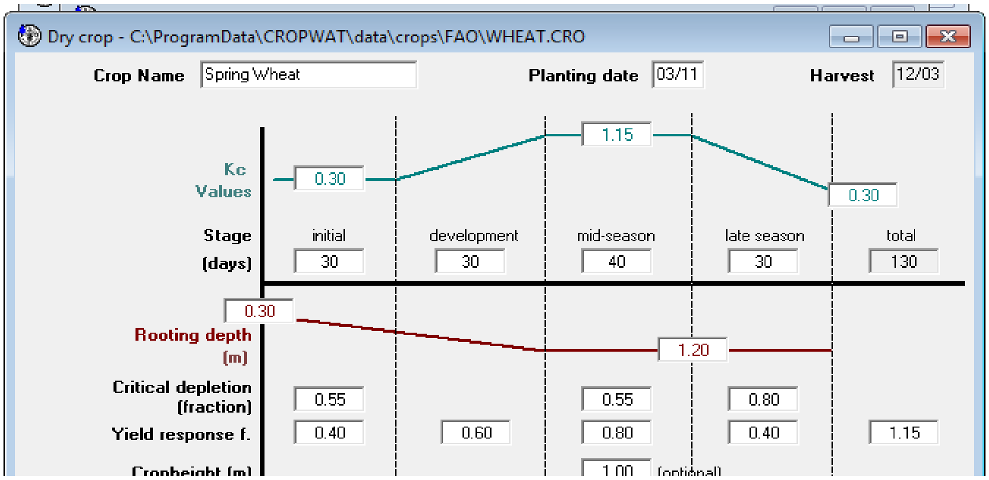


Figure 8 Spring wheat crop data (CROPWAT 8.0)

Furthermore, below in figure 9, the maize crop window is displayed:

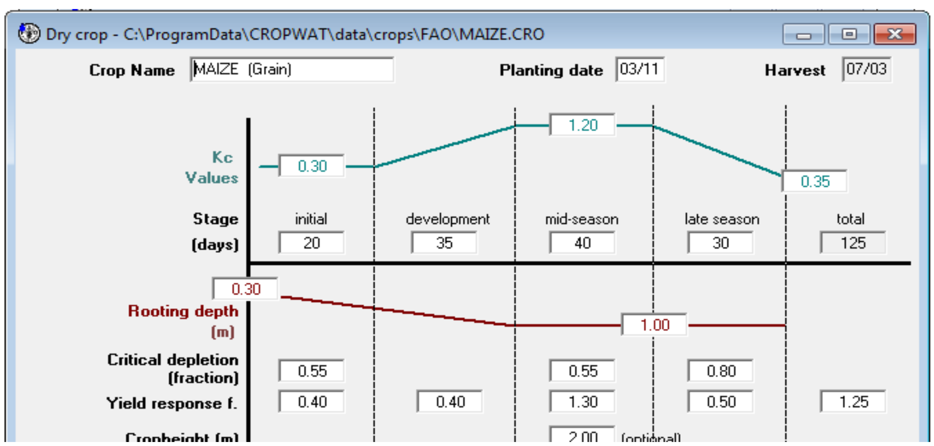


Figure 9 Maie crop data (CROPWAT 8.0)

Initializing and Reviewing Soil Data

The soil in SIWA is generally red sandy. The type of soil was chosen, and the soil table displayed the soil data, as shown in figure 10 below:

Initializing and Reviewing Crop Pattern Data

The chosen crops patterns then were selected and initialized from the Crop Pattern button, as shown below (figure 11):

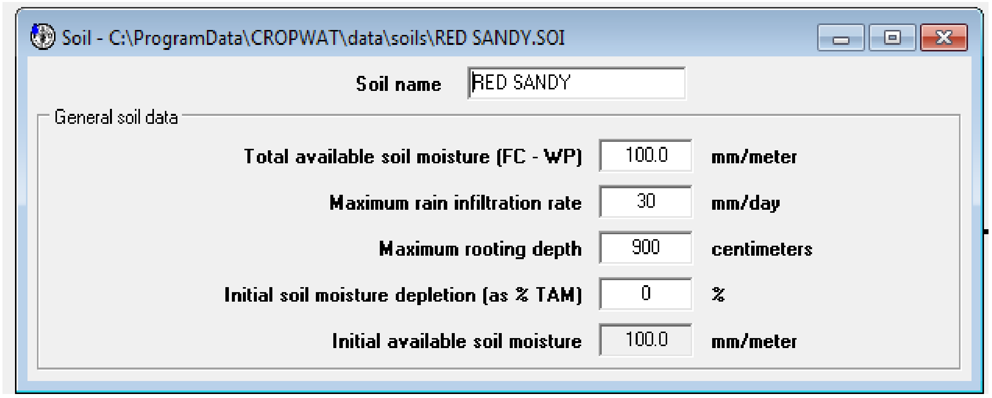


Figure 10 Soil characteristics in SIWA (CROPWAT 8.0)

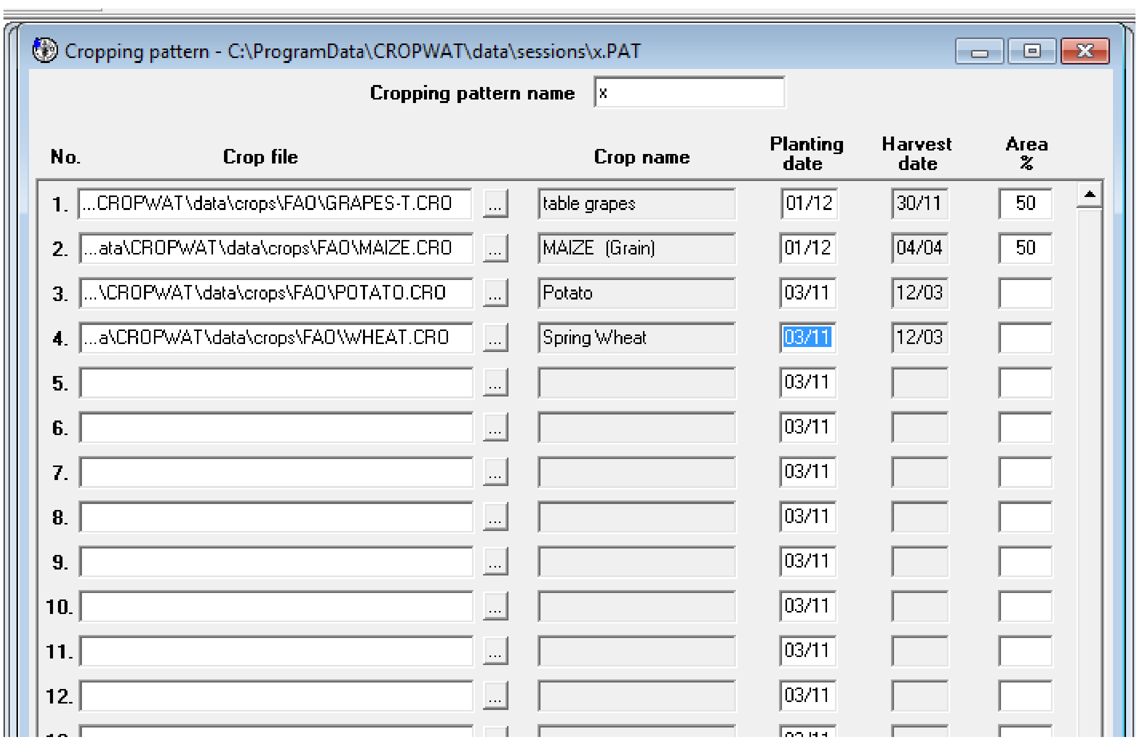


Figure 11 Defining the crops chosen for this paper (CROPWAT 8.0)

Results and Analysis

After initializing and reviewing all data and applying any required configuration, the program is ready to provide the principal results/outputs as described next.

Crop Water Requirements

The water requirements for each crop selected, which is one of the most important outputs of CROPWAT 8.0, is shown in detailed tables for each crop as displayed below (figure 12 and figure 14):


Scheme Supply

ETo station SIWA

Rain station SIWA

Cropping pattern ÉÕiÕÌÚÞÕ

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation deficit												
1. Spring Wheat	39.4	80.6	110.9	22.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.9
2. table grapes	14.7	19.3	32.5	45.1	95.0	186.3	209.1	191.6	150.4	113.0	51.5	9.3
3. Potato	49.7	80.0	123.2	45.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.5
Net scheme irr.req.												
in mm/day	1.1	2.2	2.9	1.1	0.9	1.9	2.0	1.9	1.5	1.1	0.5	0.4
in mm/month	34.1	62.1	89.8	33.9	28.5	55.9	62.7	57.5	45.1	33.9	15.5	12.3
in l/s/h	0.13	0.26	0.34	0.13	0.11	0.22	0.23	0.21	0.17	0.13	0.06	0.05
Irrigated area	100.0	100.0	100.0	100.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	100.0
(% of total area)												
Irr.req. for actual area	0.13	0.26	0.34	0.13	0.35	0.72	0.78	0.72	0.58	0.42	0.20	0.05
(l/s/h)												

Figure 12 Water requirements for some crop in SIWA as indicated by CROPWAT 8.0

Scheduling

Scheduling shows the crop irrigation proposed schedule that CROPWAT 8.0 presents based on the data fed to the program and the expertise built in the system. Figure 13 below shows the schedule proposed by CORPWAT 8.0.

Scheme

Scheme Supply shows the details and values should be considered for irrigation of the crops, as shown in figure 14 below:

Rapid analysis of the results indicates that the results are close and matching the values and recommendations for the human expertise's crop water requirement.

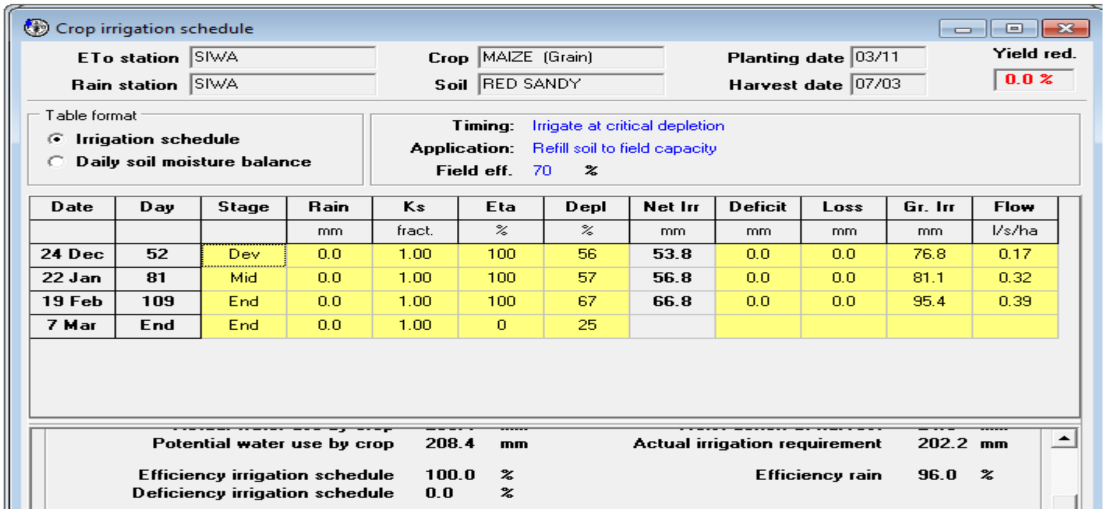


Figure 13 Scheduling details for maize crop as indicated by CROPWAT 8.0

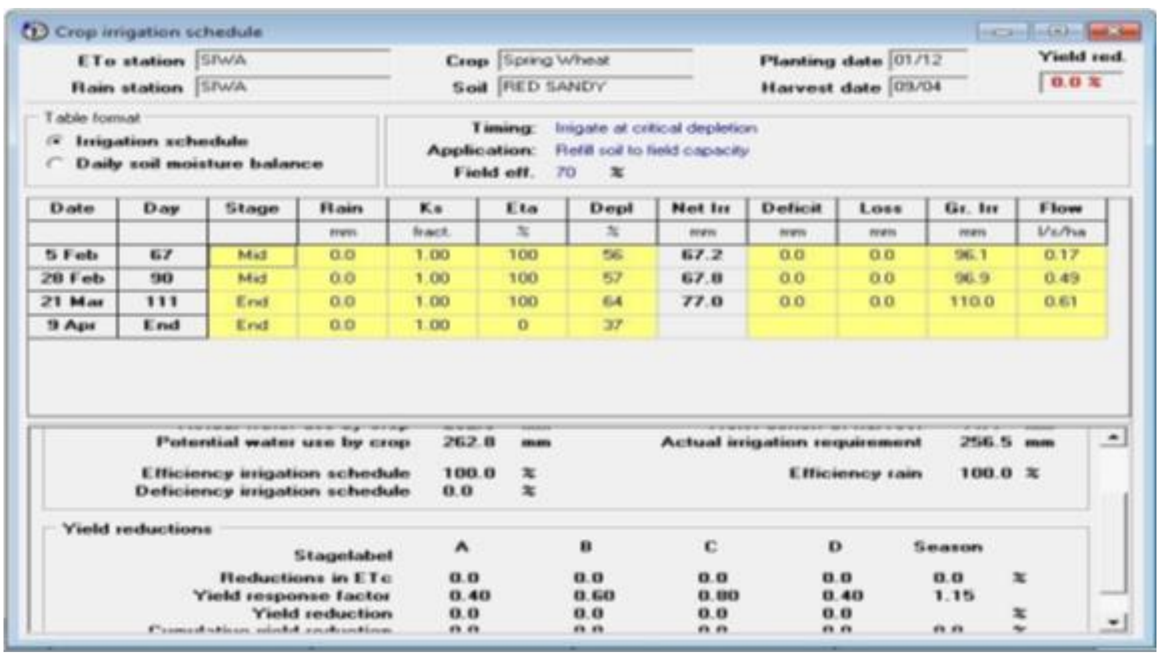


Figure 14 Proposed scheme for the selected crops in SIWA as indicated by CROPWAT 8.0

Data Visualization

CROPWAT 8.0 has a powerful data visualization engine.

Below (figures from 15 to 18) are a close-up details on the climate and weather in the subject area.

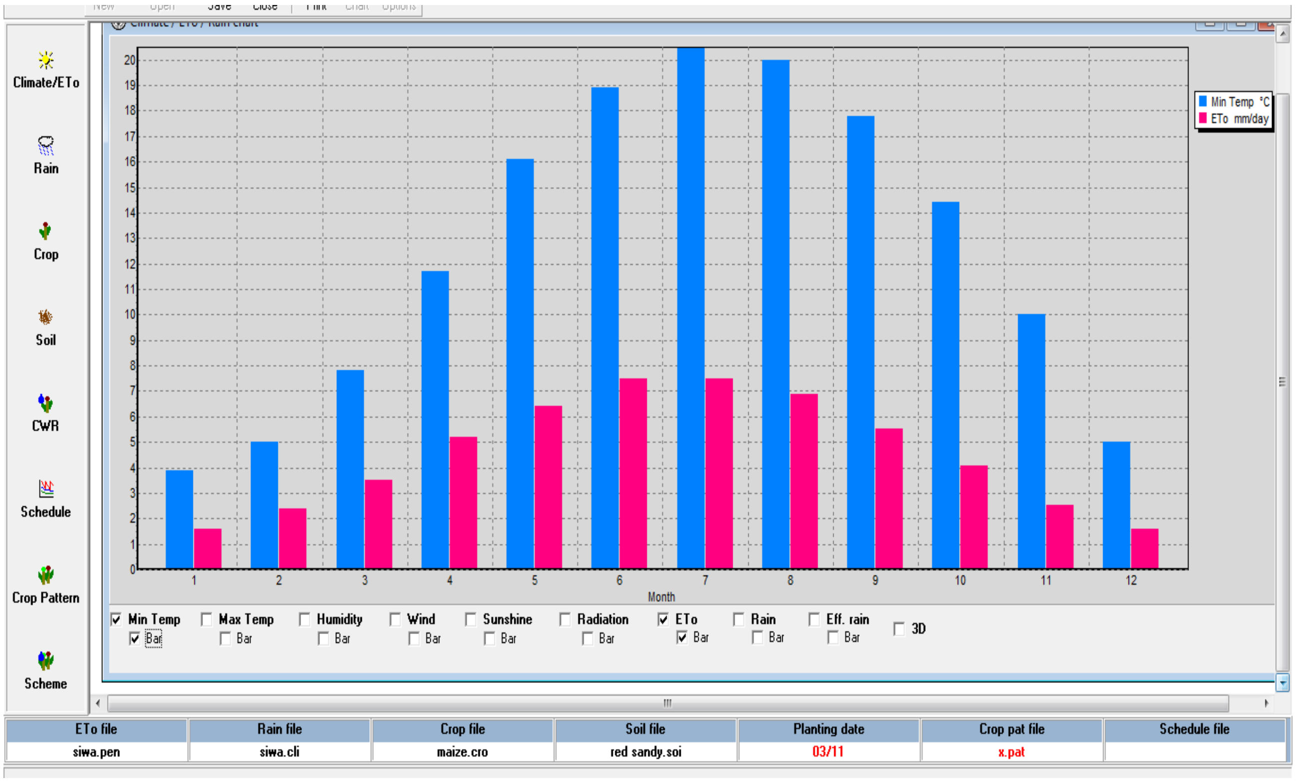


Figure 15 Temperature variations in SIWA as shown in CROPWAT 8.0

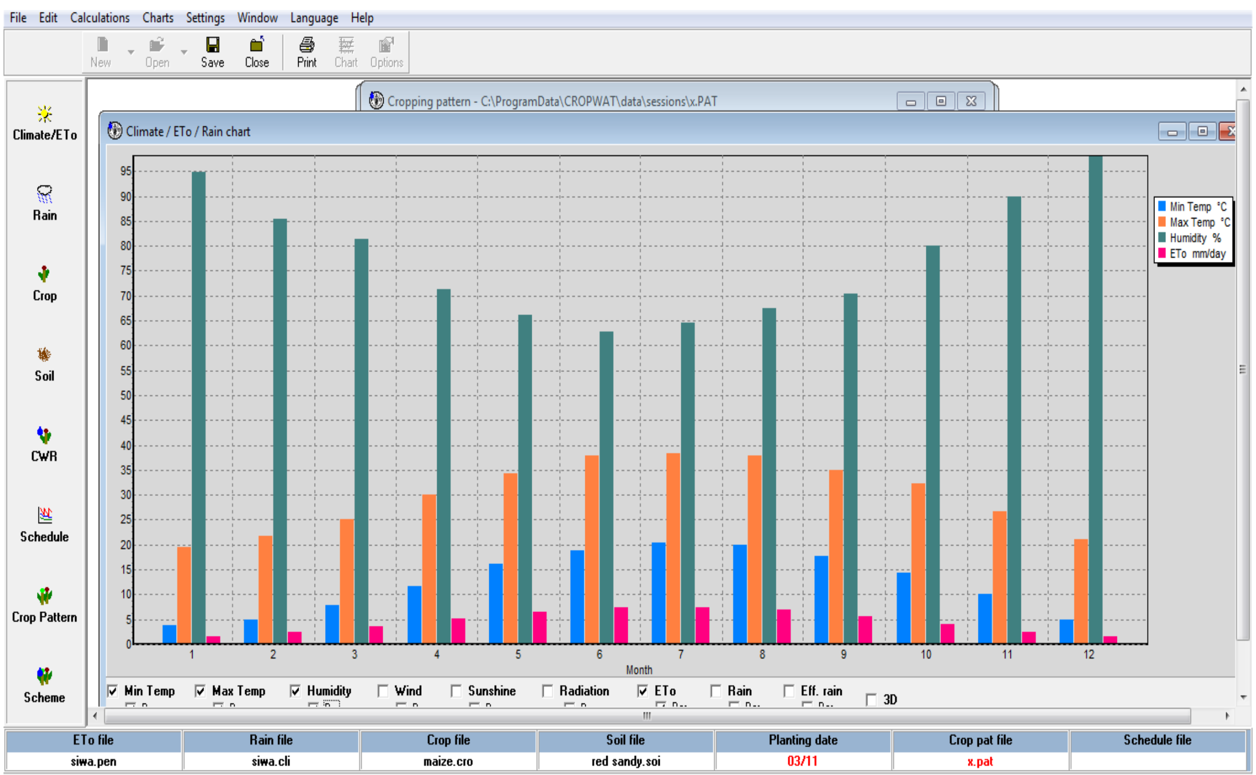


Figure 16 Rain relations with ETo as in SIWA as shown in CROPWAT 8.0

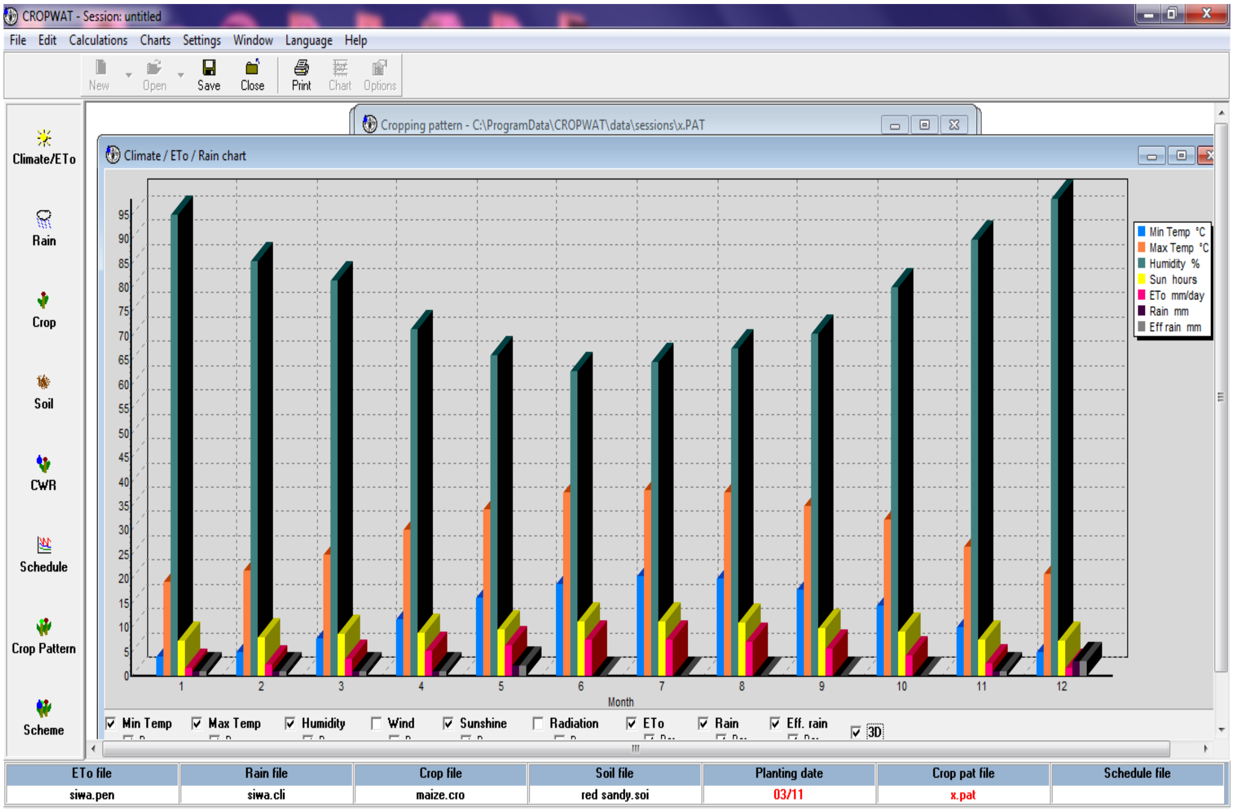


Figure 17 Relation between some weather elements in SIWA as shown in CROPWAT 8.0

The chart below (figure 18) displays relations of different climate features with the rain and ETo.

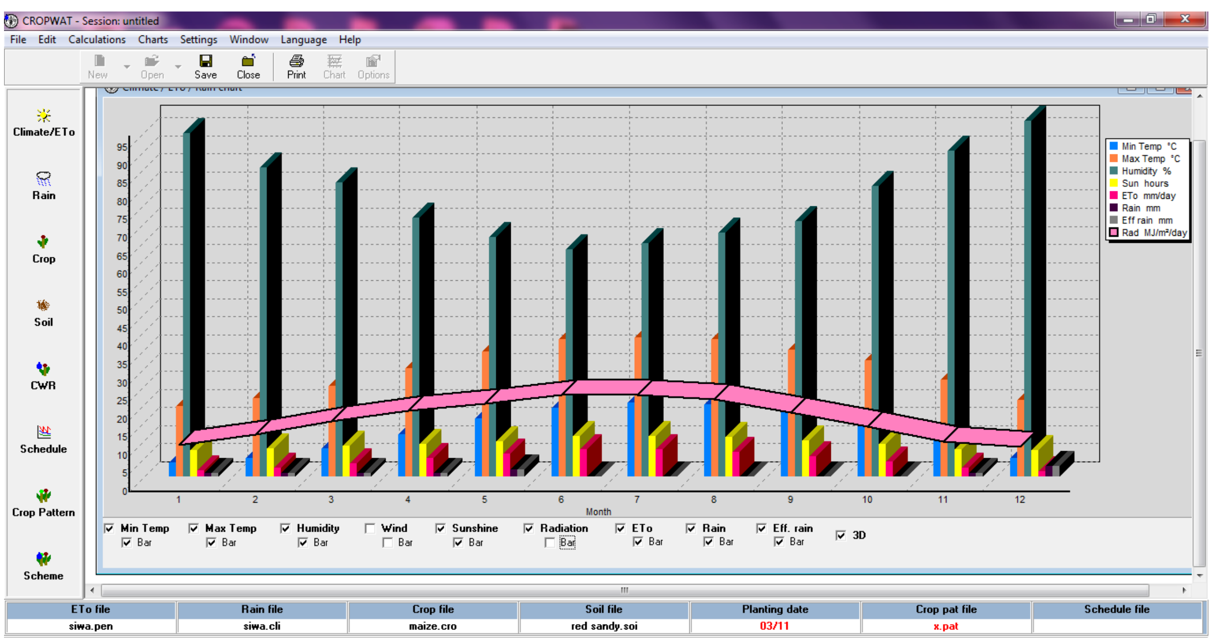


Figure 18 Different climate features in SIWA shown in CROPWAT 8.0

Conclusion and Recommendations

1. A review analysis comparing the values and guiding resulting from CROPWAT 8.0 with the values taken and prepared without software assistance would confirm that the results generated by CROPWAT 8.0 match the recommendations and guidance provided by the human expertise. This conclusion is logical as CROPWAT 8.0 and CLIMWAT 2.0 are just applications based on and designed by human expertise and knowledge.
2. Another real point is the friendly environment and the simple structure of these programs. This simplicity is required as the programs are not designed only for the specialized or expert skilled literate people; but also to the public, including the farmers in the developing countries who are among the most impoverished population and are not expected to have a high level of education in the most of the time.
3. Using CROPWAT 8.0 and CLIMWAT 2.0 is highly recommended to estimate the water requirements and provide general guidance and instructions on a scientific basis on managing agricultural and irrigation activities to increase productivity while maintaining the resources for the individuals and the communities. This recommendation is valid as these two programs are widely used and respected in the world, sponsored by a respected specialized international non-for-profit organization (FAO), easy to learn, simple to use in a friendly environment, accurate, fast, can enhance productivity and save resources, and are free of charge.
4. Regional and local authorities are encouraged to spread and motivate using these programs among the targeted populations, focusing on the farmers. Special training courses should be conducted, and efforts should be made to make the required hardware and software available for the poorest people to benefit from such systems. Partnerships with NGOs and Social Corporate Responsibilities from international and local origins should be established for that purpose.
5. It is recommended also to make these applications available in Arabic, as they are already available in English, French, Russian, and Spanish.
6. CROPWAT 8.0 for Windows and CLIMWAT 2.0 for CROPWAT are useful for farmers to estimate the potential risks and helpful in decision-making regarding the crops.
7. It is important for the agricultural extension and advisory teams to be close to the farmers to advise and instruct them on the demand for water for the various crops grown to raise the productivity of the crops.
8. Agricultural consulting teams should have substantial training and upskilling on using the CROPWAT 8.0 program because these programs are essential in helping farmers.
9. Choosing suitable crops for planting at the right time is a very important factor as it allows optimum use of water from rainfall/ precipitation and from all available water sources.
10. It is necessary to give priority to crops that are easy to adapt to local climatic conditions, as they are more resistant to water poverty, diseases and damages that could be affected by crops and soil.

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