

# Mode-Based Assessment of Irrigation Scheduling using CROPWAT 8.0 under different soil Types in Babel: Case Study in Iraq

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## ABSTRACT

Iraq's economy is highly dependent on agricultural income, and irrigated agriculture requires an adequate supply of serviceable water. The current study aims to apply a computer model that predicts the water requirement for two types of soil (sandy and sandy loam) and suggests a plan to protect the modified water management. A numerical model (CROPWAT model) is implemented in this study based on the climate data and crop coefficient values of the plants that were established depending on the soil types. The agricultural area that lies in the city of Babel in Iraq is utilized in two locations for this study. The results explained that the total CWR of vegetables, barley, and wheat was determined to be 32.2 mm/dc, 35.1 mm/dc, and 33.5 mm/dc, respectively, for total growth periods of 92, 120, and 129 days in the years 2020–2024. Also, the maximum values of the net and gross irrigation requirement in two types of soil are 166 and 111.4 m, respectively. Moreover, the raising ratios of the gross depth when comparing between sandy and sandy loam soil types for the three classes of crops are 26%, 33%, and 52%, respectively. A comprehensive irrigation schedule plan that estimates the irrigation requirements for the other crops cultivated in the area may be created using this information, which contributes to improving the irrigation management and increasing the productivity of agriculture. The study recommended to irrigate the field according to a critical depletion scenario, which emphasizes water application prior to the crop going under water stress.

**Keywords:** CROPWAT model; irrigation requirement; soil types; constant depth; irrigation interavall.

## Graphical abstract



## Recommended Citation

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## 1. Introduction

A major issue for Iraq is the paucity of water resources as the country's population and economy expand. When it comes to important resources like water, it's essential to mention that it's both a human necessity [1]. Iraq's economy is highly dependent on agricultural income, and irrigated agriculture requires an adequate supply of serviceable water of good quality [2–4]. Due to the huge growth of industry and agriculture in recent years, the water environment has become noticeably affected, and as a result, it is vulnerable to all local disturbances regardless of their location [4–7]. Kar & Verma et al. (2005) [8] discovered that appropriate irrigation timing can increase field crop water production based on crop evapotranspiration with provided irrigation during critical growth stages. Gabr (2022) [9] enhanced irrigation efficiency by planning the water management and improving the produce crops based on requiring less water. [10] examines the effect of climate change on the water needs of wheat crops in Northern Algeria along four different Shared Socioeconomic Pathways (SSPs): SSP126, SSP245, SSP370, and SSP585. The study used CROPWAT 8.0 software to forecast and evaluate changes in the reference evapotranspiration (ET<sub>o</sub>) and crop water requirements (CWR) for wheat over future decades and downscaled climate projections from the CMCC-ESM2 model. [11] calculated the present irrigation water needs for crops in four sub-basins of the Ba River basin using the CROPWAT 8.0 model, ArcGIS software, and the CMhyd model. The results were projected until 2100 using the CMIP6 model's scenarios. It concluded that the amount of water needed for irrigation tends to rise as a result of climate change, particularly during the dry months. [12] utilized CROPWAT8.0 software to estimate crop water requirements, crop irrigation requirements, and irrigation scheduling under climate change in Central Afghanistan. The general circulation model (GCM) and local organizations generated the climatic variables for the period 1990 to 2020. It concluded that the wheat requires three irrigations in the baseline scenario and four in subsequent scenarios due to the rising in water requirement. The study aided and supported the Iraq agricultural development and sustainable use of water resources, enhancing the region's food and economic security. The research objects 1- assessment cultivated water requirements of chosen crops in Iraq Babel city employing the CROPWAT 8.01 software and 2- calculate irrigation requirements and produce an irrigation schedule for the chosen crops with two types of soil in Babel city.

## 2. Materials and Methods

### 2.1 Description of study area

Two locations were selected in this study that lie in Babel City in the middle of Iraq. The first site lies at coordinates 44 longitude and 33.8 latitude, while the second zone is situated between 44E and latitude 33N, as shown in Figure 1. Most of the study area was cultivated with wheat, corn, and barley. The type of soil in the first location was loamy sand, while the second site appeared sandy. [13]. The weather stats of the case study appear cold and rainy in the winter and hot and dry in the summer. Thus, the average monthly rainfall depth is 55 mm in January. Also, the maximum and minimum temperatures are 50 and 2 in winter and summer, respectively. The agriculture density is 35% in the summer and 90% in the winter [14]. Finally, it showed that the elevation of the topography ranged between 30 and 35 m.

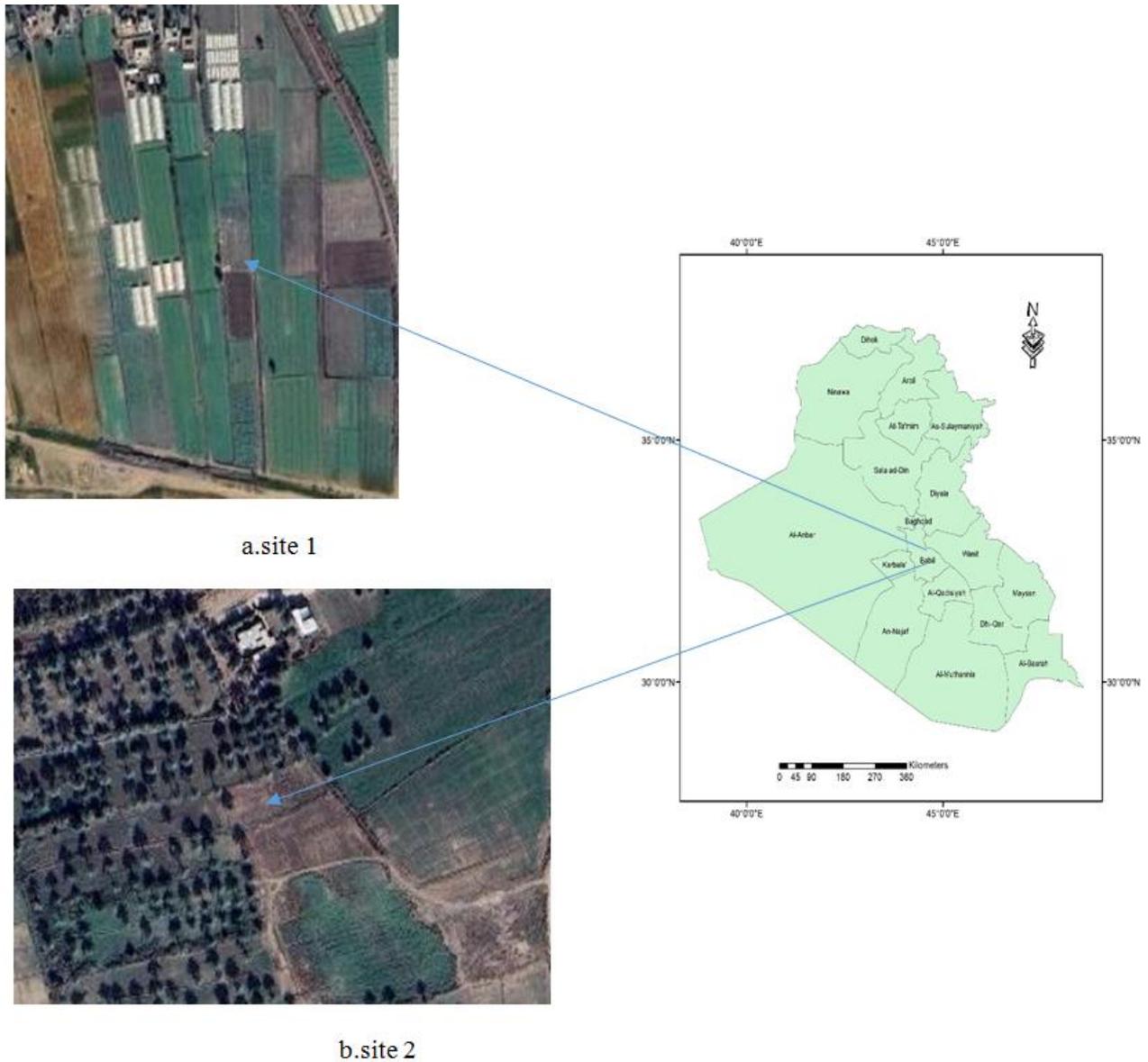


Fig 1.The position of the study area[15].

## 2.2 CROPWAT model

CROPWAT model Version 8.01 of the Food and Agriculture Organization of the United Nations was developed by the Land and Water Development Division of FAO. It was employed for multipurpose uses such as crop water requirements, irrigation requirements, irrigation schedules, etc., based on climate, crop, and soil data [16]. All climate data and soil and crop types were deemed input data. While the irrigation schedule was considered the output. In addition, the software is based on two approaches for estimating the water requirement, such as constant depth and constant interval [17 - 20].

## 2.3 Crop water requirement

In the CROPWAT model, reference crop evapotranspiration was calculated using the FAO-approved Penman–Monteith technique, which is generally required to predict the  $ET_0$  [21]. Also, the model based on the Penman formula for determining the actual evaporation for the crop requirement is listed by equation (1) below.

$$ET0 = \frac{0.408 \cdot \Delta \cdot (Rn - G) + U2 \cdot (es - ea) \cdot \gamma \frac{900}{T + 273}}{\Delta + \gamma \cdot (1 - 0.34 \cdot U2)} \quad (1)$$

Where is  $ET0$ : is the reference evapotranspiration (mm /day),  $G$  is

- soil heat flux density (MJ m<sup>2</sup> /day),  $e_s - e_a$  : vapor pressure deficit, (mb),  $Rn$  : the net radiation at the crop surface (day<sup>-1</sup>),  $U2$  : the wind at 2 m height,  $T$  : average air temperature (°C),  $\Delta$  : saturation vapor pressure , mb/°C,  $\gamma$  : modified psychrometric constant, (mb/°C).

The monthly  $ETC$  of crops was determined using the Penman–Monteith equation and the crop coefficient ( $Kc$ ) of the chosen crops during particular growth phases. Evapotranspiration rate is computed as:

$$ETC = ET0 \cdot Kc \quad (2)$$

where the reference crop evapotranspiration in millimeters per day is  $ET0$ , the crop coefficient is dimensionless, and the crop evapotranspiration in millimeters per day is  $ETC$ .

The USDA SCA's recommended method was used to determine the effective rainfall in the CROPWAT 8.0 model [22].

This approach was used to calculate the monthly effective rainfall using Equations (3) and (4).

$$ER = \text{Total } R \cdot (125 - 0.2 \cdot TR) / 125 \quad (3) \text{ for } R < 250\text{mm}$$

$$ER = 125 + 0.1 \cdot R \quad (4) \text{ for } R > 250\text{mm}$$

Where  $R$  is Total Rainfall and  $ER$  is the the monthly effective rainf (mm) and Gross irrigation requirement ( $GIR$ ), which accounts for irrigation system water losses, and monthly net irrigation requirement ( $NIR$ ) were calculated using equations (5) and (6).

$$NIR = ETC - ER \quad (5)$$

$$GIR = NIR / 72\% \quad (6)$$

### 3. Methodology

The methodology of the study included several stages:

- 1- Data collection such as weather data, soil type and crop type.
- 2- Apply climate crop based on station and then export the data to cropwat.
- 3- Input the two soil types .
- 4- Input the crop factors.

Running the model through two approaches and then estimating the crop requirement. The stages of the methodology were illustrated in Figure 2.

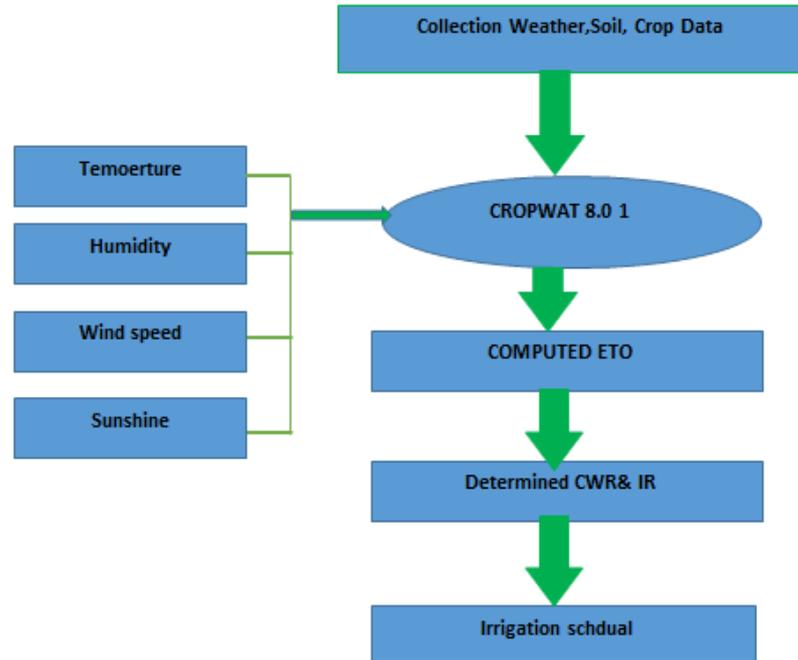


Fig 2: Illustrated methodology of the case study

In this study, cropwat 8.01 models for estimating water requirements through utilized meteorological data maximum and minimum temperature, total rainfall, and relative humidity for both locations in Babil City. Usually, the fluctuation of water requirements is primarily impact by soil types and weather parameterrs such as precipitation, temperature, humidity, and the crop types. The water requirement is directly influenced by rainfall, while temperature and humidity have a direct impact on evapotranspiration rates, which has an impact on overall irrigation schedules.

## 4. Results and discussion

### 4.1 Result of reference evapotranspiration (Eto)

The mean monthly evapotranspiration (2020–2024) in mm was calculated using the daily scale ETO value, which is shown in Table 1. The region's ETO was found to be highest in July at a rate of 6.95 mm/day, followed by August at a rate of 6.66 mm/day. The lowest ETO occurred in January (0.9 mm/day).

Table1: Represented the variation of mean monthly Eto

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
Unite	°C	°C	%	km/day	hours	MJ/m <sup>2</sup> /day	mm/day
<b>January</b>	4.2	18.0	54	3	11.0	14.0	0.90
<b>February</b>	4.7	19.0	55	1	11.3	17.3	1.31
<b>March</b>	9.0	27.0	44	2	12.0	21.9	2.49
<b>April</b>	10.0	30.0	34	1	15.0	29.4	3.85
<b>May</b>	13.0	35.0	37	3	16.0	32.8	4.96
<b>June</b>	21.0	44.0	40	3	17.0	34.8	6.37
<b>July</b>	23.8	48.0	42	3	17.0	34.4	6.93
<b>August</b>	23.0	50.0	44	3	17.0	32.7	6.66
<b>September</b>	23.3	48.0	43	3	16.0	28.0	5.24
<b>October</b>	22.4	43.0	45	3	14.0	21.2	3.38
<b>November</b>	19.2	34.0	50	2	13.0	16.4	1.73
<b>December</b>	16.6	30.3	51	2	12.0	13.8	1.16
<b>Average</b>	15.8	35.5	45	2	14.3	24.7	3.75

### 4.2 Result of rainfall & effective rainfall

Three successive month (June, July and August) saw the lowest effective rainfall (0 mm), meaning that a significant amount of irrigation water will be needed to replenish the soil's moisture content. It was concluded that the effective rainfall levels were sufficient for the duration of the monsoon season. Figure 3 shows the Babel region's monthly total and effective rainfall. In terms of effective rainfall, march had the most (32 mm), followed by February (30 mm). Also, the values of Kc of three types of crop were established as shown in figure 4.

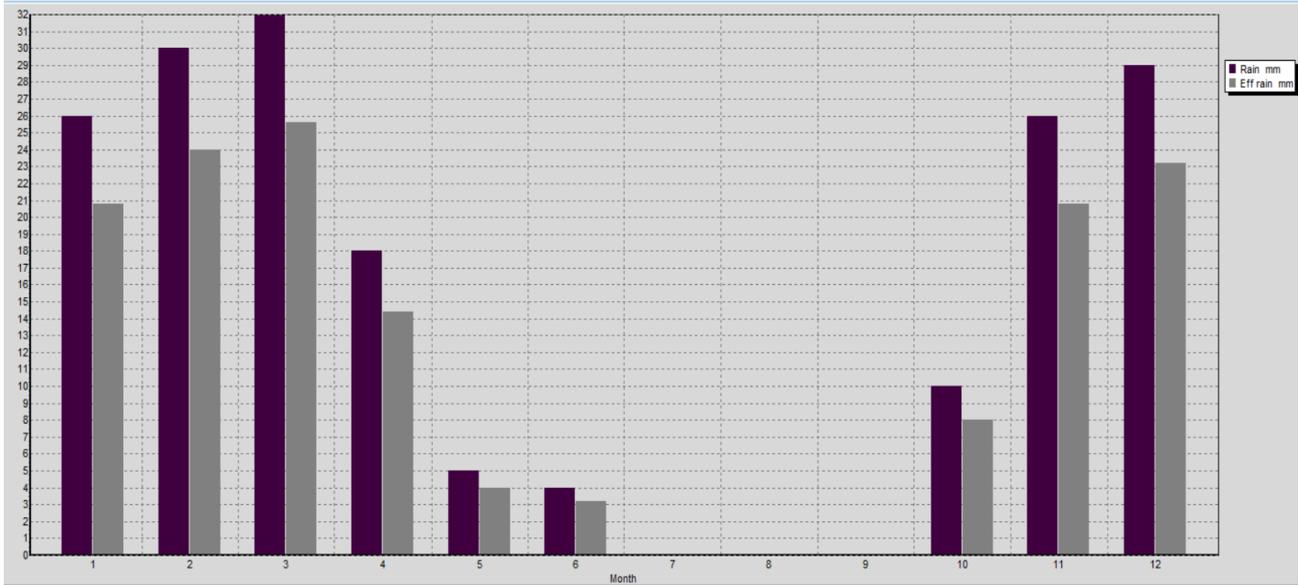
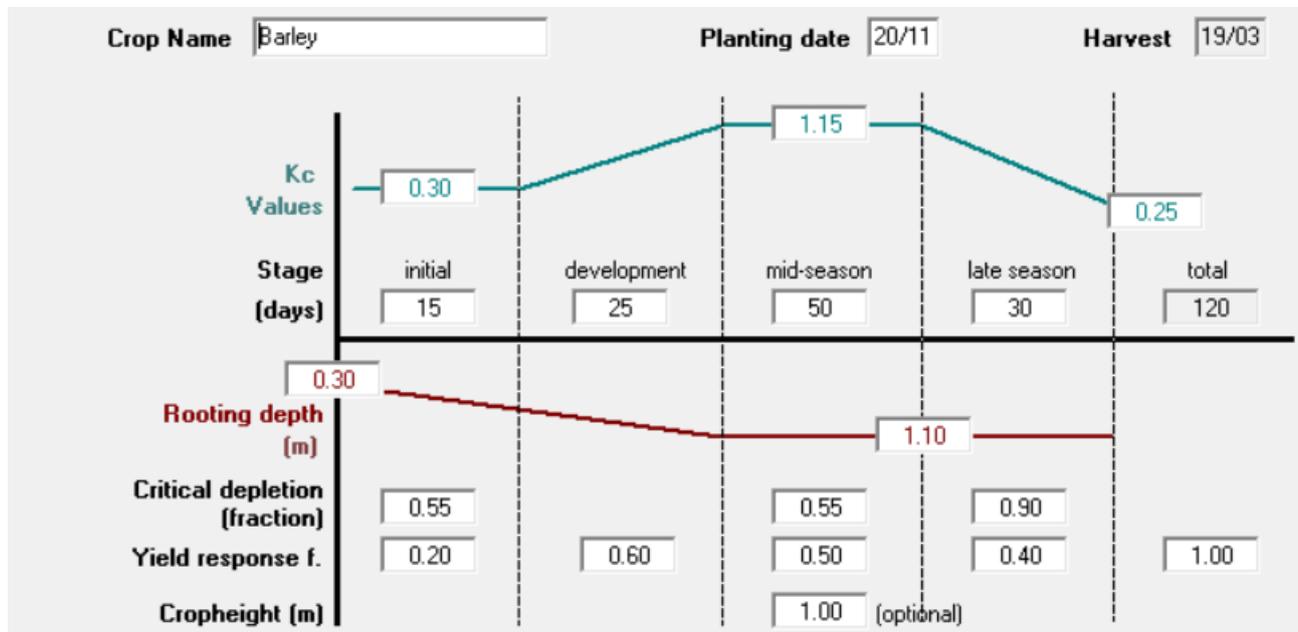
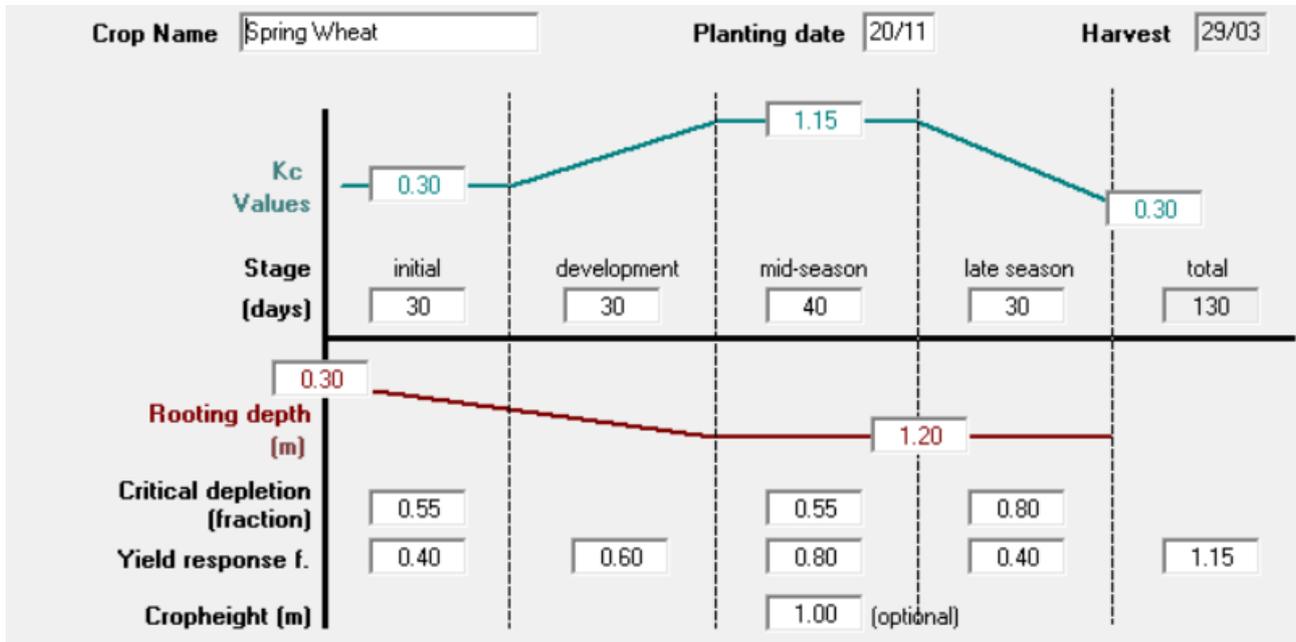


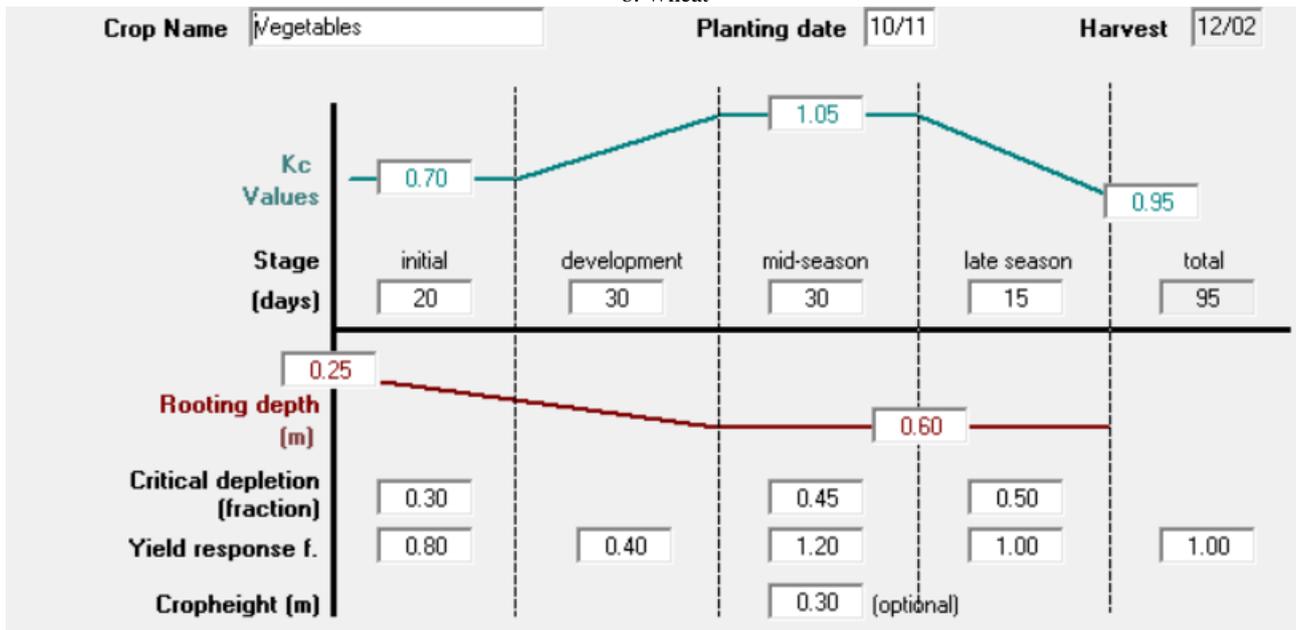
Fig 3. Shows both rainfall and effective rainfall



a. Barley



b. Wheat



c. Vegetable

Fig 4. Represented relationship between plant stage with kc

### 4.3 Irrigation requirement

The annual actual evapotranspiration (ETC) and NIR of a few chosen crops cultivated in Babil City are displayed in Table 2. For the years 2020–2024, the total CWR of vegetables, barley, and wheat was determined to be 32.2 mm/dc, 35.1 mm/dc, and 33.5 mm/dc, respectively, for total growth periods of 92, 120, and 129 days. The NIR values of vegetables, barley, and wheat were 14.5 mm, 54.9 mm, and 251.7 mm, respectively. The high CWR resulted from insufficient rainfall, which was essential for soil restoration. The crop's irrigation needs must therefore be met by delivering more irrigation water.

Table 2: Represented the value of actual evatranspiration and NIR for barley

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Nov	1	Init	0.30	0.66	0.7	0.6	0.7
Nov	2	Init	0.30	0.49	4.9	7.4	0.0
Nov	3	Deve	0.37	0.54	5.4	7.5	0.0
Dec	1	Deve	0.67	0.90	9.0	7.6	1.4
Dec	2	Mid	0.99	1.14	11.4	7.9	3.5
Dec	3	Mid	1.11	1.18	13.0	7.6	5.4
Jan	1	Mid	1.11	1.09	10.9	7.0	3.9
Jan	2	Mid	1.11	1.00	10.0	6.7	3.3
Jan	3	Mid	1.11	1.15	12.6	7.1	5.5
Feb	1	Late	1.09	1.28	12.8	7.7	5.1
Feb	2	Late	0.86	1.13	11.3	8.1	3.3
Feb	3	Late	0.61	1.03	8.3	8.2	0.1
Mar	1	Late	0.36	0.76	6.9	7.9	0.0
$\Sigma$					117.3	91.2	32.2

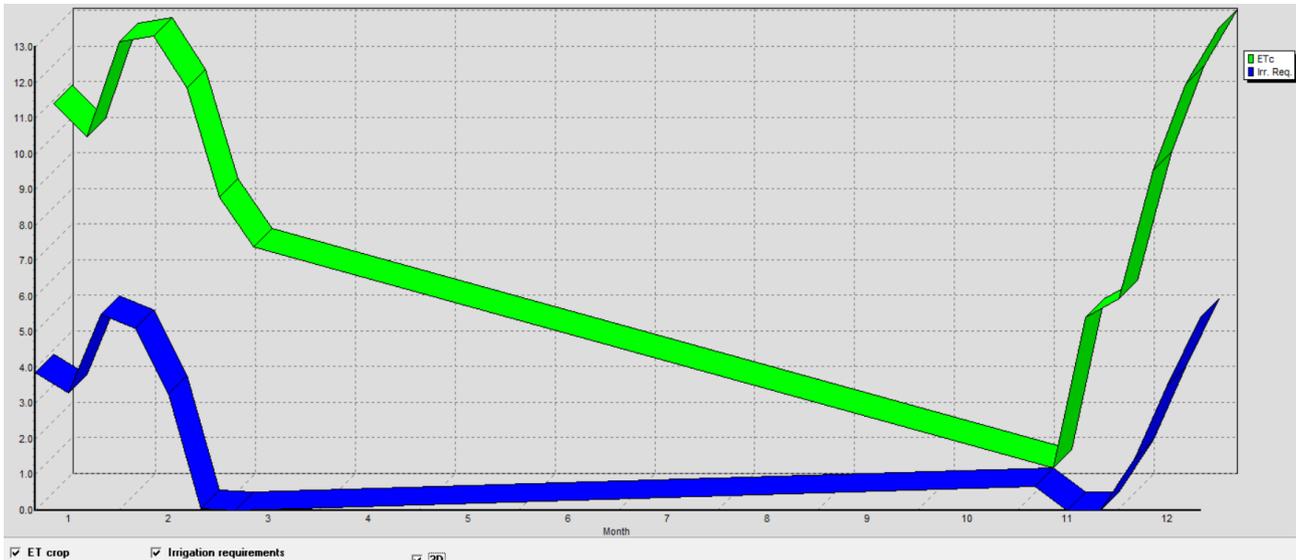
Table3: Represented the value of actual evatranspiration and NIR for wheat

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Nov	1	Init	0.30	0.66	0.7	0.6	0.7
Nov	2	Init	0.30	0.49	4.9	7.4	0.0
Nov	3	Init	0.30	0.44	4.4	7.5	0.0
Dec	1	Deve	0.30	0.41	4.1	7.6	0.0
Dec	2	Deve	0.48	0.55	5.5	7.9	0.0
Dec	3	Deve	0.76	0.81	8.9	7.6	1.3
Jan	1	Mid	1.03	1.02	10.2	7.0	3.2
Jan	2	Mid	1.11	1.00	10.0	6.7	3.3
Jan	3	Mid	1.11	1.15	12.7	7.1	5.6
Feb	1	Mid	1.11	1.30	13.0	7.7	5.4
Feb	2	Late	1.09	1.43	14.3	8.1	6.3
Feb	3	Late	0.91	1.55	12.4	8.2	4.2
Mar	1	Late	0.66	1.39	13.9	8.7	5.2
Mar	2	Late	0.41	1.02	9.1	8.2	0.1
$\Sigma$					124.2	100.3	35.1

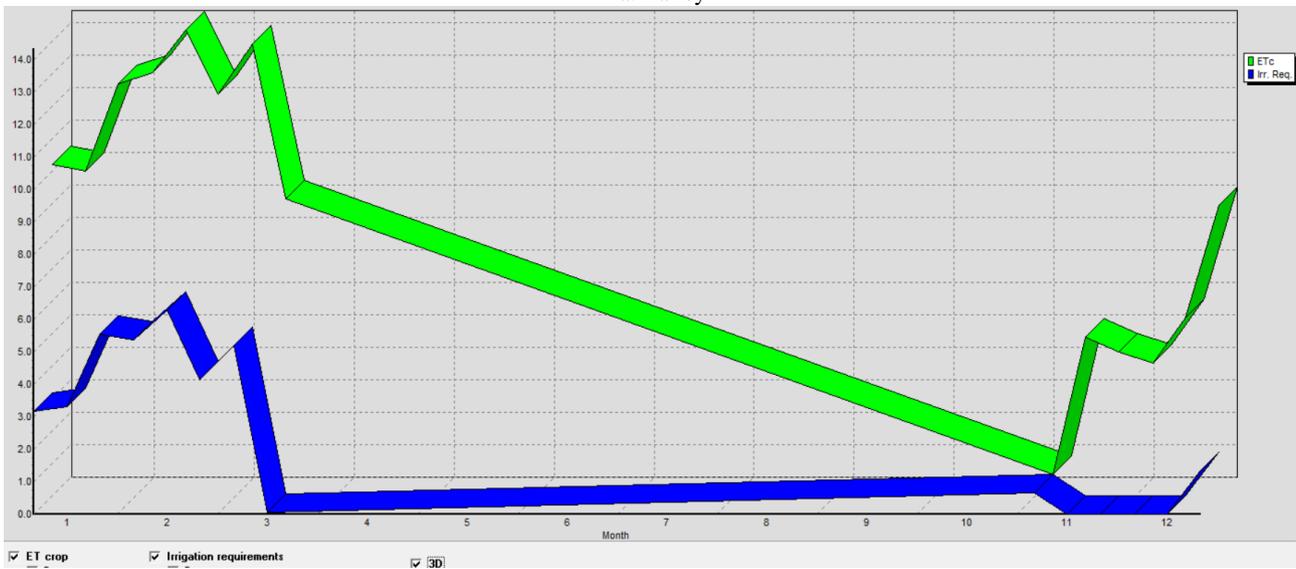
Table4. Represented the value of actual evatranspiration and NIR for vegetables

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Nov	1	Init	0.70	1.55	1.6	0.6	1.6
Nov	2	Init	0.70	1.14	11.4	7.4	4.0
Nov	3	Deve	0.70	1.03	10.3	7.5	2.8
Dec	1	Deve	0.77	1.04	10.4	7.6	2.8
Dec	2	Deve	0.88	1.01	10.1	7.9	2.2
Dec	3	Mid	0.99	1.06	11.6	7.6	4.0
Jan	1	Mid	1.02	1.01	10.1	7.0	3.0
Jan	2	Mid	1.02	0.92	9.2	6.7	2.5
Jan	3	Late	1.02	1.06	11.6	7.1	4.5
Feb	1	Late	0.96	1.13	11.3	7.7	3.7
Feb	2	Late	0.93	1.21	2.4	1.6	2.4
$\Sigma$					100.1	68.7	33.5

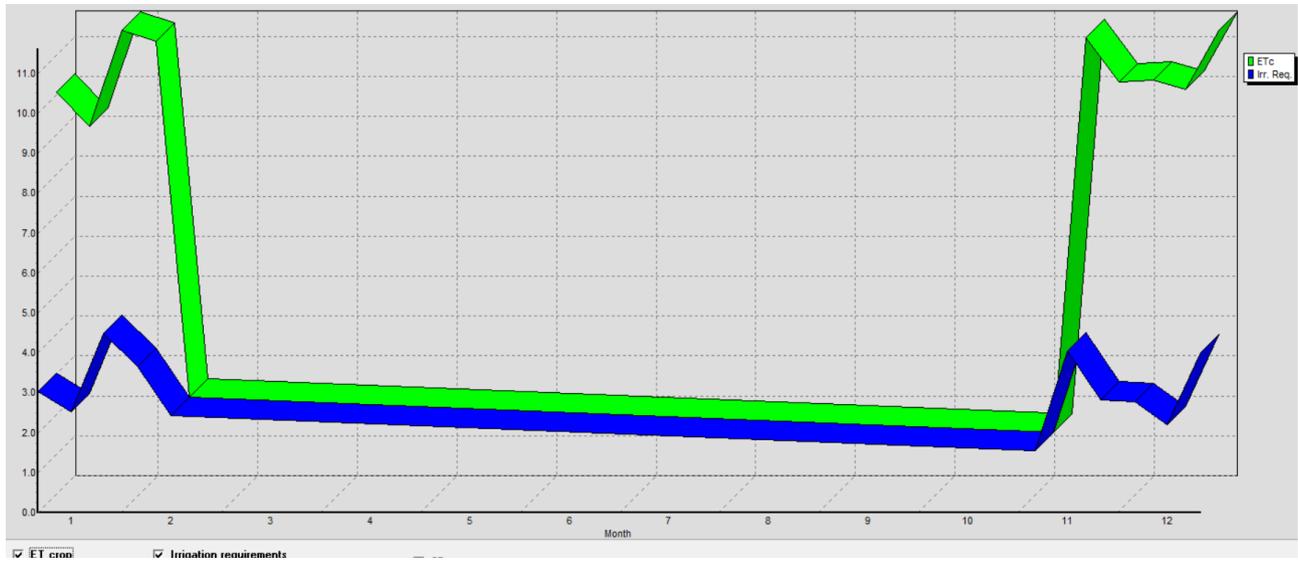
Irrigation needs for barley and wheat covered the actual crop evapotranspiration (ETC) in November only. While in Vegetables, both actual crop evapotranspiration (ETC) and actual crop evapotranspiration were compatible for the growing period from February to November between 2020 and 2024, as shown in Figure 5.



a. Barley



b. Wheat



c. Vegetables

Fig 5. Actual crop evapotranspiration ETC and irrigation needs for three crops

4.4 Irrigation scheduling

The irrigation scheduling strategy for sandy soil types with classes of crops such as barley, wheat, and vegetables at different stages of growth is displayed in Table 5. The total number of irrigation applications needed for every crop at every growth stage was determined from scheduling data. It showed the maximum and minimum values of net irrigation depth for three crops were estimated at 72.8, 80.1, 30.2, 40.3, 33.1, and 12.7 mm, respectively. At the same time, it showed the highest and lowest values of gross depth were 105,111.4, 32.1, 60, 48, and 17 mm, respectively. While in sandy loam, the maximum values of net irrigation depth are 103.1, 112, and 50.1, and the minimum values are 70.3, 66, and 18 mm. Corresponding to that, the maximum and minimum values of gross depth are 143,166,679,890.4 and 22 mm, respectively, as shown in Table 6. Generally, the wheat crop class required a high value of both net and gross irrigation depth for the two types of soil and the minimum values for vegetable crops. Also, it showed that the values of both depths were increased for sandy loam soil types. Moreover, it showed that the values of both depths were increased for sandy loam soil types. the raising ratios of the gross depth when comparing between Sandy and Sandy Loam soil types for the three classes of crops are 26%,33%and 52% respectively. finally, The CROPWAT 8.0 model was simulated the Daly soil retention for three crops as shown in figure 6.

Table5. Represented the irrigation schedule for three crop for Sandy

Crop type	Day	Depletion%	Max NIR mm	Max GIR mm
Barley	159	55%	72	105
Wheat	120	50%	80.1	111.4
Vegetables	60	50%	30.2	32.1

Table 6: Represented the irrigation schedule for three crop for Sandy Loam

Crop type	Day	Depletion%	Max NIR mm	Max GIR mm
Barley	159	55%	103	143
Wheat	120	50%	112	166
Vegetables	60	50%	50.1	67

The topographically varied conditions play a major role in varying flow velocity values [23]. Somani conclusion, the model able to assert that the cropwat model, when combined with long-term climatic data, is capable of provide accurate data for the specific water requirements of crops [24]. Singh prove that rice crops require the most water, followed by onions, according to the results. The biggest water requirements for rice crops are said to occur in January and April [25]. On the other hand, the onion crop requires the most water in January and December.

## 5. Conclusions

Crop water planning and the agricultural sustainability of a region depend heavily on estimating crop water requirements and comprehending the irrigation schedule. In the Babel region, CROPWAT 8.01 was used to evaluate the CWR, NIR, and GIR of wheat, barley, and vegetables. The results of the study can be utilized to create water-saving strategies such as scheduling irrigation and using water effectively during shortages. The values of both depths (NIR and GIR) were increased for sandy loam soil types. Generally, the wheat crop class required a high value of both net irrigation and gross depth for the two types of soil. In contrast, the vegetable crops need a minimum quantity when compared with the barley and wheat crops. Also, the outcomes appear to be that the raising ratios of the gross depth when comparing between sandy and sandy loam soil types for the three classes of crops are 26%, 33%, and 52%, respectively. The study emphasizes the importance of adjusting irrigation to suit the specific needs of each crop, either through strategic scheduling or modifying net and gross irrigation depths, to improve water management and maximize crop production in the region. Finally, it showed that the barley required more periods for irrigation when compared with both types of crops, and the study concluded that both types of soil selected in this study did not affect the period of irrigation schedule. In order to maximize yield, it is recommended to irrigate the field according to a critical depletion scenario, which involves water application prior to the crop going under water stress.

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## Conflict of Interest

The authors state no conflict of interest.

## Data availability statement

Most datasets generated and analyzed in this study are in this submitted manuscript. The other datasets are available on reasonable request from the corresponding author with the attached information.

## Statements and Declarations

We declare that the manuscript was done depending on the personal effort of the author, and there is no funding effort from any side or organization, as well as no conflict of interest with anyone related to the subject of the manuscript or any competing interest.

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