

Estimation of Irrigation Scheduling Derived by FAO Model for Wheat, Barley, and Tomatoes in Kirkuk Governorate in Iraq

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Abstract

This study aimed to manage water resources efficiently for decreasing water consumption. The FAO-CROPWAT 8.0 model was used to estimate reference evapotranspiration (ET₀), crop water requirements and optimal irrigation scheduling for decreasing water irrigation water the important cultivated crops in Kirkuk Governorate, Iraq (wheat, barley and tomato) using weather data. The findings indicate that water demand varies among crops and growth stages, reflecting seasonal and ecological conditions. The crop water requirements of the three examined crops were found to be in the following sequence: Wheat 1505 > Tomatoes 867.2 > Barley 134.2. The study revealed that the wheat, barley crops do not require irrigation because they are winter crops and rely on rain-fed agriculture during the winter. Tomato was high in the beginning because the reference evapotranspiration (ET₀) was high and the rooting depths were shallow. This rate decreased in the middle of the growing season when the rate of evapotranspiration reduced and roots systems had been formed more and this is the time when the soil retained its maximum moisture content. These results highlight the effectiveness of CROPWAT and CLIMWAT as decision-support tools for optimizing water allocation, recommend for guiding irrigation scheduling, and improving crop productivity. The study provides valuable insights for farmers, planners, and policymakers to enhance water resource management, adapt cropping patterns, and promote sustainable agriculture under increasing water scarcity and climate change.

Keywords: Irrigation Scheduling, FAO CROPWAT, Wheat, Barley, Tomatoes, Kirkuk, Iraq

Introduction

In spite of Iraq's various freshwater resources that can be used for crop irrigation, the country has faced with water scarcity in recent decades as a result of dams that were constructed on the Tigris

and Euphrates rivers in its upstream region, decrease in rainfall, and traditional surface irrigation methods that are inefficient [1]. Due to the agriculture sector being the main water user, irrigation

efficiency and precise estimation of crop water requirements (CWRs) play a key role in sustainable water resource management [2].

FAO estimates that 75% of irrigated land in Iraq is moderately saline, and 20–30% of potentially arable irrigated land is not used because of salinity problems. Irrigation in Iraq is primarily used in summer for crops, vegetables and fruits. Wheat and barley are the main winter crops irrigated, accounting for approximately one-third to one half of the total agricultural production in Iraq. Emphasis for reforms should be placed on modern irrigation techniques (sprinkler and drip) and on key crops, water efficiency and improvement of soil conditions. It is also important to sensitize the farmers on the importance of conserving water and using modern technologies in irrigation [3].

Food and Agriculture Organization (FAO) developed CROPWAT 8.0 software package is widely used to calculate crop evapotranspiration, irrigation scheduling and water requirement. It is accompanied by its database CLIMWAT 2.0, which contains climatic data from more than 5000 meteorological stations all over the world and monthly records of temperature, rainfall, wind speed, solar radiation, and humidity [4].

Reducing water use and increasing crop productivity are critical solutions to these challenges that can be achieved through scientific estimation of CWRs and optimization of irrigation schedules as well as the development of drought and salinity tolerant cultivars [5].

The past decade has seen growing interest in applying the CROPWAT 8.0 model to estimate water requirements and schedule irrigation for major crops in Iraq, given the country's increasing water scarcity

resulting from climate change and the construction of dams in upstream countries [1]. In Dhi-Qar Governorate, Ewaid et al. (2019) used the CROPWAT 8.0 model with CLIMWAT 2.0 data to estimate the water requirements of several major crops, relying on the Penman-Monteith method to calculate reference evapotranspiration (ET₀) and the USDA method to estimate effective rainfall. They found that water requirements amounted to 1,142 mm/decade for wheat, 203.2 mm/decade for barley, and 1,180 mm/decade for tomatoes, with water demand peaking during dry seasons and declining during rainy seasons. In a similar study conducted in Basra Governorate, [7] estimated the water requirements of certain vegetables and fruits using the CROPWAT model, with irrigation requirements for wheat at 99.1 mm and for barley at 103.1 mm, while tomatoes required 470.3 mm of total water and 415.4 mm of net irrigation water. The results indicated that the irrigation rate is high at the beginning of the season due to high ET₀ values and shallow root systems, then decreases in the middle of the season as root systems develop and the soil's moisture-holding capacity increases. In the central region (Al-Qadisiyah Governorate), Al-Bahathy et al. [8] used the CROPWAT model to optimize irrigation scheduling for major crops, and the results showed that evapotranspiration peaks in July and reaches its lowest levels in January. Effective rainfall was 23.2% for wheat and 26.3% for barley, and irrigation requirements were 99.1 mm and 103.1 mm, respectively, confirming that summer crops such as rice require significantly more water than winter crops. . In the Abu Ghraib irrigation project, Alsamarray et al. (2025) examined the compatibility of cropping patterns with climate change using the CROPWAT 8.0 model, and found that the net irrigation water requirements (NIWR) for most crops are projected to increase by up to 80% by 2075

compared to historical rates, The results also showed that wheat, alfalfa, and eggplant are highly sensitive to climate change, while barley, cowpeas, and spinach demonstrated greater adaptability, underscoring the need to adjust agricultural strategies and adopt modern irrigation techniques and drought-tolerant varieties. . All of these studies agree that the CROPWAT model is an effective and accurate scientific tool for estimating water requirements and scheduling irrigation, thereby contributing to the rational

management of water resources and mitigating the negative effects of improper irrigation, particularly in semi-arid regions such as Nineveh Governorate, which is the site of the current study. This study uses the CROPWAT 8.0 program software to determine water requirements and irrigation schedules for three major crops (tomato, barley and, wheat) to enable more efficient water resource planning and irrigation management in Kirkuk province, Iraq.

Material and Methods

2.1. Description of Study Area

The Kirkuk Governorate is located in northern Iraq, about 250 km north of the capital Baghdad. Kirkuk Governorate covers an area of approximately 9,679 km². It is bordered by the governorates of Erbil, Mosul and Salah al-Din (Figure 1).

The climate in Kirkuk is classified as hot desert. Temperatures are highest in summer, reaching 42–43 °C in July and

August, and lowest in winter, dropping to 2–4 °C in January. Monthly rainfall in winter (mainly from November to April) ranges between 60–80 mm, while in summer (June to August), rainfall is almost absent (0–2 mm). The number of rainy days per month is around 10–14 days

in winter, compared to only 0–1 day in summer [11].



Figure 1. The Kirkuk Governorate in northern Iraq

2.2. CROPWAT 8.0 Model Description

It is a computer program developed by the Food and Agriculture Organization (FAO) which uses a series of mathematical equations to aid in the decision making process on the use of reference evapotranspiration (ET_0), crop water

requirements (CWR), and irrigation scheduling and irrigation water requirements (IR) based on rainfall, soil, crops, and climate related data.

General datasets are available for various crop characteristics, local climate and soil properties. It aids in optimizing irrigation program and irrigation water allocation

2.3. Data Requirement

The rainfall data, climatic data, soil data and crop data are the four primary data types necessary to use the CROPWAT program [12].

The climatic data for the year 2024 was obtained from the Kirkuk meteorological

The CLIMWAT database contains seven annual long-term climatic parameters, the geographic location (longitudes and latitudes) and the altitude above sea level of the station. The parameters are: Minimum temperature (min °C), Maximum temperature (max °C), Wind speed (WS km/h), Average relative humidity (RH%), sunshine duration (hrs), rainfall (mm), and Effective rainfall (mm) According to [4].

Soil characteristics include initial soil moisture loss, total available soil moisture, maximum rooting depth, maximum rain infiltration rate and were drawn from the

based on various cropping patterns under either irrigated or rainfed (rain-dependent) conditions (FAO, 2018).

station (Table 2) within the CLIMWAT 2.0 database. CLIMWAT is a climatic database that can be used with the CROPWAT program to compute irrigation demands for a variety of crops at a large number of climatic stations around the world (FAO, 2018).

Wheat, barley and tomato crop data were retrieved from FAO Irrigation and Drainage Paper No. 56 and fed to the CROPWAT program. These data comprise root depth, crop coefficient, critical depletion fraction, yield response factor and crop growth stage length [7]. Sowing dates were set based on Iraqi Agricultural Operations Manual [13].

FAO CROPWAT 8.0 model gives detailed information on soils in the vicinity of the meteorological station.

2.4. The Reference Evapotranspiration (ET₀)

Transpiration which can be defined as water loss from plant surface and evaporation which is water loss from the soil surface both processes occur together, when combined are referred to as evapotranspiration (ET₀). Reference

evapotranspiration is the sum of all the processes that lead to water loss in a reference crop with a height of 0.12 m, an albedo of 0.23 and fixed canopy resistance of 70 s m⁻¹ [17]

In the Windows environment, CROPWAT model is used to estimate ET using wetting Olsen tables in conjunction with FAO

Penman–Monteith equation, where most parameters are derived from weather data. This equation can be written to :

$$\lambda ET = [\Delta(R_n - G) + P_a C_a (e_s - e_a)/r_a] / [\Delta + \gamma(1 + r_s/r_a)] \dots\dots eq.(1)$$

R_n = net radiation.

G = soil heat flux.

$(e_s - e_a)$ =
vapor pressure deficit of the air.

r_s = surface resistance.

r_a = aerodynamic resistance.

P

= average of air density at constant pressure

C_p = specific heat of the air.

vapor pressure and air temperature.

When applying the standard characteristics of the hypothetical crop and the reference height for wind speed measurement (2 m), Equation (1) can be simplified to:

$$ET_0 = [0.408\Delta(R_n - G) + \gamma 900/(T + 273)u_2(e_s - e_a)]/[\Delta + \gamma(1 + 0.34u_2)] \dots \text{eq.(2)}$$

ET_0
= reference Evapotranspiration (mm

T
= average daily air temperature at 2 m (°C).

u_2 = wind speed at 2 m (m/s).

e_s = saturation vapor pressure (kPa).

e_a = actual vapor pressure (kPa).

Crop water requirement means the amount of water required which is equivalent to the loss from a field under cultivation due to evapotranspiration in mm/day. The CWR is estimated according to the crop evapotranspiration (ET_c) which is calculated by the following equation (Pereira et al., 2015).

$$ET_c = K_c \times ET_0 \dots \text{Eq. (3)}$$

K_c = crop coefficient, which is the ratio of the crop's ET_c to the reference evapotranspiration (ET_0).

It combines the effect of four factors that make the crop different from the reference grass: the albedo (reflectance) of the crop-soil surface, the crop height, canopy resistance, and soil surface evaporation.

The evapotranspiration rates are different at various growth stages of the crop and for this reason the K_c values will change throughout the crop development period, which can be subdivided into four main stages: the initial stage, the crop V stage, the mid-season stage and the late-season stage [17].

2.5. The Irrigation Water Requirement (IR)

The CROPWAT model represents the water balance of the root zone, which is calculated at day level, includes the water balance at the end of the day [18], and is given by the following equation:

$$Dr_{,i} = Dr_{,i-1} - (P - RO_i) - I_i - CR_i + ET_{ci} + DP_i \dots \text{Eq. (4)}$$

Where:

Dr_i = root zone depletion at the end of day i (mm).	I_i = net irrigation depth on day i infiltrated into soil (mm).
Dr_{i-1} = water content in the root zone at the end of previous day (mm).	Cr_i = capillary rise from groundwater table on day i (mm).
p_i = precipitation on day i (mm).	ET_{ci} = crop evapotranspiration (ET) on day i (mm).
RO_i = surface soil runoff on day i (mm).	DP_i = lost water of the root zone on day i (mm).

2.6. The Irrigation Scheduling

Irrigation scheduling refers to determining both the appropriate quantity of water and the optimal timing for its application. Using the CROPWAT model, values of

ET_0 , CWR, and IRs are estimated to design irrigation schedules under various management practices and water availability scenarios [19].

Results and Discussion

The input data for both CROPWAT and CLIMWAT programs included Iraq region, climatic station located in Kirkuk, crop type, planting date and soil texture (heavy clay). After inputting these data, the software generated ET_0 , effective rainfall

and total irrigation needs of each crop. More results from CROPWAT are presented in the subsequent tables and figures. Table 1 presents details related to the four studied crops, while Table 2 illustrates the crops features of the Kirkuk region.

Table 1. show the data of the crops under this study

Crop Growth (Days)				Rooting Depths (cm)	Critical Rooting Depletion	Planting and Harvesting Date	Crops
Late season	Mid Season	Crop Develop.	Initial				
30.0	45.0	40.0	30.0	100.0	0.30	15-March 6 August	Tomatoes (<i>Solanum lycopersicum</i>)

30.0	50.0	25.0	15.0	110.0	0.55	15- November 24 March	Barley (<i>Hordeum Vulgare</i>)
30.0	40.0	30.0	30.0	120.0	0.55	15 November 24 March	Wheat (<i>Triticum aestivum</i>)

Estimation of Reference Evapotranspiration and Effective Rainfall

The monthly ET_0 values generated by the CROPWAT model are presented in Table 2. Results indicate that ET_0 reaches its maximum during summer months thus it rising water requirement and water amount for cultivated crops irrigation (Wheat, Barley, and Tomatoes) due to elevated temperatures, with the highest rate recorded in July (16.03 mm). In contrast, it declines during the winter season, reaching its lowest level in December (5.9 mm) as a result of reduced temperatures.

The variation in ET_0 values reflects the influence of different climatic The ET_c values were relatively low during the initial and final phases of growth, when crop productivity is limited, and

conditions in the study area. Low relative humidity, elevated temperatures, and speed winds contributed to higher evapotranspiration rates during the dry periods [20].

Tables 3–6 demonstrate that ET_c values increase throughout the crop development stages and decline slightly toward the later phases. These fluctuations are linked to the crop coefficient (K_c), as represented in Eq. 3. Although the K_c values showed only minor changes, they were not constant across the growth stages, indicating the seasonal water demand of the crops [21].

reached their maximum at the mid-growth stages for all three crops.

Table 2. Climate characteristics and ET_0 of the Kirkuk area.

ET_0 (mm/day)	Rad (MJ/m ² /day)	Sun (hours)	Wind (km/day)	Humidity (%)	Max Temp. °C	Min Temp. °C	Month
1	6,1	1,9	218	89	15	6,5	January
1,63	7,5	1,8	294	80	15,9	7,1	February
3,1	10,1	2,3	445	68	20,4	8,6	March
5,4	10,8	1,4	583	65	30,8	17,1	April

9,04	13,7	2,6	672	41	32	19	May
9,59	11,8	1	600	24	30	18	June
15,74	14,5	3	759	24	43,6	29,9	July
15,6	13,4	3	716	22	43,5	29,8	August
11,29	11,5	2,9	577	28	38,1	25,3	September
6,03	8,4	2,1	489	51	30	16,9	October
2,18	6,4	1,9	308	76	21,1	10,8	November
0,97	5,9	2,3	266	92	16	6,3	December
6,8	10	2,2	494	55	28	16,3	Average

Effective rainfall (mm) available moisture before loss of surface runoff and deep percolation. It is one of the most important factors in determining how much water crops actually need. The main characteristics of rain amount, frequency and intensity differ both over time and space, and such detailed knowledge is

necessary to optimize water use efficiency [4].

In this study, the average rainfall data for 2024 indicates that the proportion of rainfall effectively utilized was 114.7% for wheat, 99% for barley, and 70% and for tomatoes.

3.2. Crop Water Requirement of Tomatoes, Barley, and Wheat

The results of water requirement estimates in tables 3-6 presented the crop water requirements of the three examined crops, expressed in mm/dec, were found to be in the following sequence: Wheat 1184.1> Tomatoes 867.2>Barley 134.2. using the Food and Agriculture Organization (FAO-CROPWAT) model for the three crops studied in Kirkuk Governorate for the full growing season, confirming that water demand varies depending on crop type, growth stages, and season length [14]. The stage, its highest during mid-growth, and then declines sharply in the late stages [23,7].

Furthermore, an analysis of effective rainfall and net irrigation requirements revealed that the timing of rainfall played a pivotal role in reducing the demand for artificial irrigation, as effective rainfall covered approximately 73.8% of barley's

highest values were recorded during the mid-season stage, with wheat's peak water requirement reaching 136.1 mm/decade in the third decade of May and tomatoes' reaching 102.4 mm/decade in the second decade of June, while barley's peak was relatively low at 16.9 mm/decade in the second decade of February. This is consistent with the global pattern of water requirement distribution, which reaches its lowest levels during the establishment

requirements, making it the most efficient crop in terms of winter water use. In contrast, its contribution to wheat did not exceed 14.2% and 18.1% for tomatoes due to their growing seasons extending into the dry summer months, which led to an increase in net irrigation requirements to 1,023.9 mm for wheat and 713.4 mm for tomatoes. This poses a significant challenge to water resource management

in Kirkuk, which is located in a semi-arid climate. The literature indicates that relying on locally determined crop coefficients (Kc) and improving irrigation efficiency using simulation models can mitigate water waste and environmental degradation [6],[24]. Therefore, the recommendation to expand barley cultivation and implement precise irrigation schedules for wheat and

tomatoes according to their growth stages is an urgent necessity for achieving water and food security in light of the scarcity of water resources prevailing in the region. The total water needed for crop growth is not distributed equally throughout its life span (place, climate, soil, cultivation practices, etc.), and the water requirements vary from crop to crop [25].

Table 3. Crop water requirement for wheat.

Irr. Req. mm/dec	Eff. rain mm/dec	ETc mm/dec	ETc mm/day	Kc Coeff.	Stage	Decade	Month
6	2,3	7,9	1,32	0,7	Init	2	Nov
7,5	3,5	11	1,1	0,7	Init	3	Nov
6,9	2,2	9,1	0,91	0,7	Init	1	Dec
4,5	1,7	6,2	0,62	0,71	Deve	2	Dec
0	13,8	8,4	0,84	0,84	Deve	2	Jan
0	12,1	11,8	1,07	0,89	Deve	3	Jan
4,4	8,8	13,2	1,32	0,93	Deve	1	Feb
7,2	9,9	17,2	2,15	1,01	Deve	3	Feb
12,5	15	27,5	2,75	1,05	Deve	1	Mar
35,2	13,3	48,5	4,41	1,14	Deve	3	Mar
48,5	5,7	54,1	5,41	1,19	Deve	1	Apr
78,9	4,3	83,3	8,33	1,27	Deve	3	Apr
94,7	10,7	105,4	10,54	1,3	Mid	1	May
126,6	9,5	136,1	12,38	1,3	Mid	3	May
116,4	0,1	116,6	11,66	1,3	Mid	1	Jun
92,7	0	92,7	9,27	0,83	Late	3	Jun
68	0	68	6,8	0,48	Late	1	Jul
8,9	0	8,9	4,43	0,27	Late	2	Jul
1023,9	168,6	1184,1					

Table 4. Crop water requirement for barley.

Irr. Req. mm/dec	Eff. rain mm/dec	ETc mm/dec	ETc mm/day	Kc Coeff.	Stage	Decade	Month
1,5	2,3	3,4	0,56	0,3	Init	2	Nov
1,3	3,5	4,8	0,48	0,3	Deve	3	Nov
4,5	2,2	6,8	0,68	0,52	Deve	1	Dec
5,7	1,7	7,4	0,74	0,86	Deve	2	Dec
6,1	5,1	11,2	1,02	1,12	Mid	3	Dec
1	10,2	11,2	1,12	1,14	Mid	1	Jan
0	13,8	11,2	1,12	1,14	Mid	2	Jan
3	12,1	15,1	1,37	1,14	Mid	3	Jan
7,4	8,8	16,2	1,62	1,14	Mid	1	Feb
9,7	7,2	16,9	1,69	1,03	Late	2	Feb
3,2	9,9	13,1	1,64	0,77	Late	3	Feb
0	15	13,2	1,32	0,5	Late	1	Mar
0	7,3	3,7	0,92	0,29	Late	2	Mar
43,5	99	134,2					

Table 5. Crop water requirement for tomatoes.

Irr. Req. mm/dec	Eff. rain mm/dec	ETc mm/dec	ETc mm/day	Kc Coeff.	Stage	Decade	Month
0	17	14	1.4	0.6	Init	1	Mar
0	16	15.8	1.58	0.6	Init	2	Mar
2.2	18	20.2	1.83	0.6	Deve	3	Mar
1.8	21.6	23.4	2.34	0.69	Deve	1	Apr
7.4	23.9	31.3	3.13	0.83	Deve	2	Apr
24	20.4	44.4	4.44	0.97	Deve	3	Apr
43.3	16.7	60	6	1.1	Mid	1	May
57.7	14	71.7	7.17	1.15	Mid	2	May
80	9.3	89.3	8.12	1.15	Mid	3	May
92	0.1	92.2	9.22	1.15	Mid	1	Jun
102.4	0	102.4	10.24	1.15	Mid	2	Jun
101.5	0	101.5	10.15	1.12	Late	3	Jun
93.3	0	93.3	9.33	1.01	Late	1	Jul
85.2	0	85.2	8.52	0.9	Late	2	Jul
22.7	0	22.7	7.55	0.82	Late	3	Jul
713.4	157.1	867.2					

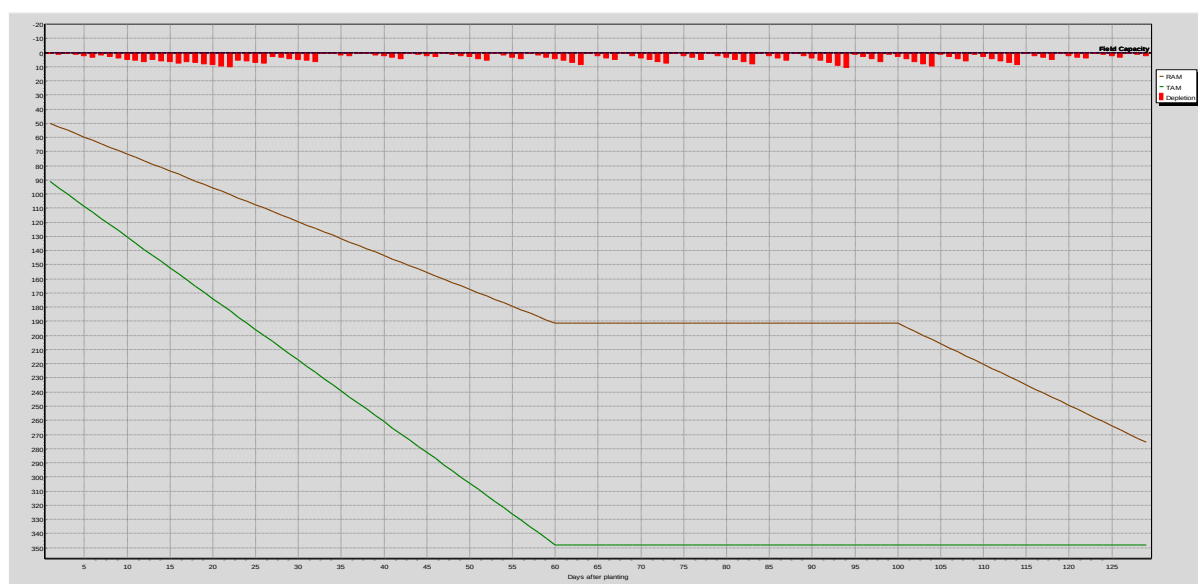
Irrigation Scheduling

Tables (7, 8, and 9) revealed that the wheat and barley crops do not require irrigation because they are winter crops and rely on rain-fed agriculture during the winter (figures 2, 3, and 4). The results of irrigation scheduling using the CROPWAT 8.0 model for wheat, barley, and tomato crops in Kirkuk Governorate showed that winter crops (wheat and barley) did not require artificial irrigation throughout their growing season, as they relied entirely on natural rainfall (rain-fed agriculture), which is consistent with the semi-arid climate of Iraq, where rainfall occurs during the winter and spring months, and is also in line with the findings of previous studies in southern Iraq, where the irrigation requirements for wheat and barley were low or nonexistent during the rainy seasons, whereas the tomato crop (summer) showed an urgent need for artificial irrigation, requiring five irrigations distributed throughout its growth stages from mid-season (May 18) until the end of the season (July 23), Total irrigation volumes ranged from 169.8 mm in the first irrigation to 198.7 mm in the fifth irrigation, with a flow rate ranging from 0.25 to 1.68 liters/second/hectare. This increase in tomato irrigation requirements at the beginning of the season is attributed to high evapotranspiration (ET_0) and the shallowness of their root system. Irrigation frequency then decreased in the middle of the season due to lower evapotranspiration rates and the development of the root system, which allowed the soil to retain as much moisture as possible. These results are fully consistent with the findings of a study by Djaman et al. (2018) regarding

the effect of growth stages and root depth on crop water requirements. They are also consistent with the findings of [6] in Dhi Qar Governorate, where irrigation requirements were 1,180 mm/decade for tomatoes, 1,142 mm/decade for wheat, and 203.2 mm/decade for barley, as well as with the study by [7]. in Basra, which confirmed that the irrigation frequency for tomatoes is high at the beginning due to high ET_0 values and shallow roots, then decreases in the middle of the season, which is consistent with the findings of the Ramadi Irrigation Project produced by [26], which indicated that irrigation requirements reached 310.4 mm for wheat and 221.8 mm for barley. Taken together, these results confirm that the CROPWAT model is an effective tool for determining optimal irrigation schedules and managing water resources rationally, especially given the increasing water scarcity in Iraq resulting from climate change and the construction of upstream dams. Relying on rain-fed agriculture for winter crops is considered an optimal strategy for reducing water consumption, while summer crops such as tomatoes require careful planning of irrigation schedules to ensure productivity while conserving water [27].

Table 7. Show the Irrigation schedules for wheat

Flow (l/s/ha)	Gr. Irr. (mm)	Loss (mm)	Deficit (mm)	Net Irr. (mm)	Depl. (%)	Eta (%)	Ks fract.	Rain (mm)	Stage	Day	Date
-	-	-	-	-	1	0	1	0	End	End	10- Mar

**Figure 2. Show the Irrigation schedules for wheat****Table 8. Show the Irrigation schedules for barley**

Flow (l/s/ha)	Gr. Irr (mm)	Loss (mm)	Deficit (mm)	Net Irr (mm)	Depl (%)	Eta (%)	Ks fract.	Rain (mm)	Stage	Day	Date
-	-	-	-	-	0	100	1	0	End	End	28- Feb



Figure 3. Show the Irrigation schedules for barley

Table 9. Show the Irrigation schedules for tomatoes

Flow (l/s/ha)	Gr. Irr. (mm)	Loss (mm)	Deficit. (mm)	Net Irr. (mm)	Depl. (%)	Eta (%)	Ks fract.	Rain (mm)	Stage	Day	Date
0.25	169.8	0.0	0.0	118.9	41	100.0	1.0	0.0	Mid	79	18-May
1.25	173.3	0.0	0.0	121.3	42	100.0	1.0	0.1	Mid	95	03-Jun
1.6	179.8	0.0	0.0	125.9	43	100.0	1.0	0.0	Mid	108	16-Jun
1.68	174.5	0.0	0.0	122.2	42	100.0	1.0	0.0	End	120	28-Jun
1.53	198.7	0.0	0.0	139.1	48	100.0	1.0	0.0	End	135	13-Jul
					26	0	1.0	0.0	End	End	23-Jul



Figure 4. Show the Irrigation schedules for tomatoes.

Conclusions

The application of the FAO CROPWAT 8.0 model provided valuable insights, showing that crop water requirements and irrigation schedules are dependent on the specific environmental and seasonal conditions of the study area. In this study the crop water requirements of the three examined crops were found to be in the following sequence: Wheat 1505 > Tomatoes 867.2 > Barley 134.2. The findings revealed that the wheat and barley crops do not require irrigation because they are winter crops and rely on rain-fed agriculture during the winter. at the beginning. This rate decreased in the middle of the growing season due to decreased evapotranspiration rates and

more developed root systems; this is also when soil reached its maximum moisture retention potential. In addition, the findings of this study may be helpful for water resource planners in future projects, and for farmers to plan the frequency and quantity of their irrigation water for these crops. A nationwide strategy is recommended to evaluate crop water requirements across all regions of Iraq where such studies are lacking. This framework could provide a foundation for agricultural development projects. Nevertheless, field validation remains essential to confirm the reliability and applicability of these software-based assessments.

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