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Research article

Optimizing Irrigation Scheduling for Major Crops in the Middle of Iraq using the CROPWAT Model to Promote Sustainable Agriculture

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Abstract

Water shortage crisis and poor water quality in Iraq represent a substantial environmental challenge caused by climate change and the constructed dams on the Euphrates and Tigris rivers in upstream countries. It is important to minimize the usage of water. Irrigated agriculture relies on surface and groundwater, rendering it the primary water consumer in Iraq. Utilizing the FAO CROPWAT 8.0 model indicated that evapotranspiration in Al-Qadisiya Governorate, the middle of Iraq, peaked in July and reached its bottom in January. A high evapotranspiration number signifies enhanced evaporation due to elevated temperatures and maximal sunlight exposure. Conversely, a low evapotranspiration value due to lower temperatures indicates lower crop water requirements. Evapotranspiration is intimately connected with the length and intensity of solar radiation. The effective rainfall values were 23.2%, 26.3 %, and 0% which were used by wheat, barley, and rice, respectively. In this study, it was obvious that the main feature of rainfall values for crops was that their amounts varied temporally. The total amount of water that wheat, barley, and rice needed for irrigation in the study area was 99.1 mm, 103.1 mm, and 404.1 mm, respectively. The data demonstrated that the irrigation need for rice (summer crops) was greater compared to other seasonal crops, such as wheat and barley. The study highlighted the fact that the crop grown in the hot season required more water consumption, which was adversely correlated with less rainfall and positively with higher Etc. On the contrary, high rainfall and lower crop evapotranspiration are prevalent in the cold season (winter season). The irrigation water needs of wheat, barley, and rice in the study area were 99.1 mm, 103.1 mm, and 404.1 mm, respectively. Furthermore, water demand remained rather stable, with a peak during the intermediate phase. This peak is essential to avoid water stress, especially during critical growth stages such as root formation stage, tillering, flowering, grain formation and dough stage, when consistent moisture is critical for optimal growth. However, water requirements declined in the later phase, reflecting the necessity of dry conditions to facilitate harvesting. The results indicated that rice requires

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longer irrigation periods than the other two crops due to the lack of rainfall during its growing

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season. The research promotes the use of CROPWAT for the calculation of crop water requirement, irrigation water requirements, and irrigation scheduling for sustainable agriculture in Iraq and globally.

Keywords: cropwat; irrigation schedules; agriculture sustainably; Iraq; crop water requirement

1. Introduction

Water and soil are essential natural resources for the lives of humans, animals, and plants (Shah et al., 2022). Freshwater is a crucial non-biological component for the health of ecosystems and human life on this planet since it is required for industrial and agricultural activities (Ewaid & Abed, 2017).

Freshwater is replenished via the water cycle; nevertheless, overconsumption may lead to supply problems especially in lands that are characterized by a dry climate (Mishra, 2023), and Iraq's climate is one of them. In addition, Iraq faces a range of problems that affect its supply of freshwater, one of which is construction of dams on the rivers that pass through its land (Tigres and Euphrates). These dams, primarily located in Turkey, expose Iraq to a severe shortage of water resources. Due to the severity of these issues, many local researchers have worked on water-related topics (Al-Bahathy & Nashaat, 2021; Nashaat & Al-Bahathy, 2022; Majeed et al., 2023; Al-Bahathy et al., 2024; Shehab et al., 2024; Al-Janabi et al., 2025; Al-Khuzaie et al., 2025; Mahdi, 2025).

Water scarcity constitutes a global challenge, especially in arid and semi-arid nations, where insufficient water resources severely impede ecological restoration, agricultural output, and industrial advancement (Ingrao et al., 2023). Globally, agriculture consumes over 70% of freshwater, industry about 20% and home uses account for 12% (UNESCO, 2024). So, it is necessary to manage and eliminate the problems associated with water scarcity by means such as modern irrigation methods and managing the irrigation process by suitable irrigation water scheduling (El-Jubouri et al., 2025).

Historically, Iraq is referred to be the land of the two rivers (Mesopotamia). Irrigation water is supplied to agricultural fields frequently to reach immediately or in adequate quantities for all irrigated farms. It possesses a comparatively ample water supply comparable to its Middle Eastern counterparts. Nonetheless, just one-third of the one-year accessible irrigation water share effectively reaches crops. (Al-Ansari et al., 2021).

Agriculture is the second-largest contributor to the country's gross domestic product in Irag (Al-Ansari et al., 2021). It accounts for approximately 4%, and can reach 25% in underdeveloped countries (FAO, 2018). In Iraq, agriculture is characterized by small farms, with many in the northern regions relying on rainwater and those in other regions on irrigation (AL-Jaf et al., 2025). Agricultural sector production in Iraq is divided into winter crops grown in the irrigated plains of the central and southern parts of the country, which account for the bulk of cereal production. The main irrigated summer crops are rice and maize (Ewaid et al., 2020)

The effects of climate change, severe drought, rising temperatures, declining rainfall, desertification, and salinity have undermined Iraq's agricultural sector (Ali, 2025). Additionally, water demand in Iraq is expected to rise from its current level of 16% to 51% by 2050 due to rising temperatures, declining rainfall, and the threat of water scarcity, is based on the declining water supply from the two rivers, the Euphrates and Tigris, which are expected to decline by 50% and 25%, respectively, by 2025 (Alwash et al., 2018).

Bread wheat is a major part of the daily diet in Iraq, it is a source of essential amino acids and constitutes about 25 percent of the consumed daily calories and protein intake

of the population (Mohammed, 2025). According to the annual statistics of the Iraqi Central Statistical Organization, winter wheat is the main crop in Iraq, accounting for approximately 70% of total grain production (Ewaid et al., 2020). Wheat-producing areas are distributed across the country, including rain-fed, irrigated, and mixed areas where climatic conditions are favorable to agricultural needs. Wheat is planted in mid-November, and the harvest period begins from mid-April to late May (Mumtaz et al., 2017).

Barley is the fourth most valuable cereal crop worldwide after wheat, maize, and rice. It is mainly cultivated to be used as animal food, barley products, and human foodstuffs (Lukinac & Jukić, 2022). Barley is normally more competitive than wheat and other grains, and its production is less sensitive to seasonal changes (Slafer & Savin, 2023). Barley is the second most commonly grown cereal after wheat in Iraq, with a similar time of growing to wheat (Abdullah et al., 2025).

In Iraq, rice is the third most important crop after wheat and barley in terms of production and cultivated area (Ewaid et al., 2020). However, Iraq is a rice importer because its rice production is insufficient to meet the needs of its population (Ewaid et al., 2021). Rice production as a major summer crop in Iraq is mainly concentrated in the Middle Euphrates region (Al-Najaf, Al-Muthanna, and Al-Qadisiyah governorates) in central Iraq (Jabaar & Abed, 2023). These crops represent 1.8% of the nation's total land area. Al-Qadisiyah's total cropped area accounts for 255000 dunum (dunum equals 2500 m^2). In 2022, the net sown area of wheat, barley, and rice covered 1000, 164000, and 51000 dunum, respectively (Al-Zamil, 2022).

The annual revenues of the Euphrates River in the study area reached 12.20 billion m^3, which decreased by 28% in 2022 compared to the previous year. Demand reached 46,131 billion m^3/year, which was 7% higher compared to previous years. The Iraqi government has taken several measures to address the water shortage in agriculture, including improving water infrastructure, enhancing irrigation efficiency, promoting the use of modern irrigation technologies, and managing sustainable water resources (AL-Hudaib et al., 2022). In this study, we looked at the scheduling and water requirements for irrigation of chosen crops (wheat, barley, and rice) in the Al-Qadisiyah Governorate, central Iraq, by using the CROPWAT model, to reduce water consumption and thus address water scarcity in the country. CROPWAT is a software application made by the FAO Organization that provides comprehensive irrigation water management techniques essential for improving water management and developing irrigation systems. CLIMWAT is a meteorological database employed by the CROPWAT program to determine crop water needs for diversified crops for many climate stations globally (FAO, 2019).

2. Materials and Methods

2.1 Study area

The Al-Qadisiyah governorate, known as the Diwaniya Governorate, is located approximately 180 km southeast of Baghdad between (31° 51′ 0″ N), and (45° 3′ 0″ E). The Al-Qadisiyah Governorate in south-central Iraq features flat alluvial plains sloping eastward from the western desert fringes. The Euphrates River flows northwest-to-southeast and is the primary water source, branching into artificial channels like the Third Alternative River, Shatt al-Shamiya, and Shatt al-Daghara for irrigation. Seasonal wetlands (e.g., Hawr Abu Zarak) and the artificial Lake Al-Hussainiya support agriculture and livestock (Olson et al., 2024). Critical water challenges include dwindling flows due to upstream dams (Turkey/Syria), soil salinization from intensive farming, and pollution from agricultural/

industrial waste, threatening its date palm/grain agriculture and buffalo-herding economies (Wedaa et al., 2022).

The Al-Qadisiyah governorate is considered one of the most important agricultural governorates in Iraq, producing important crops such as wheat, barley, and rice, among others. These crops are vital for providing food and income for rural residents. Statistics indicate that the total area of land in the governorate is 3,275,326 dunum. The area suitable for agricultural production occupies approximately 1,844,700 dunum (Wedaa et al., 2022). This study was conducted in the Al-Qadisiyah governate. Figure 1 shows the location of Al-Qadisiyah governorate in Iraq

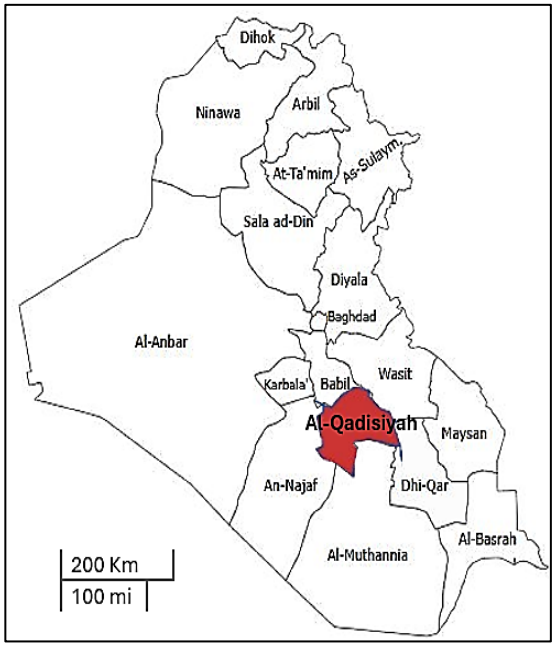


Figure 1. The map shows the study area (Al-Qadisiyah Governorate) in the middle of Iraq

2.2 Software

CROPWAT is a tool for the management of the irrigation process of land and water development for FAO Organization. This program computes evapotranspiration using the FAO Penman-Monteith-Equation. By analyzing meteorological, agronomic, and edaphic data, CROPWAT tool is used to assess crop water requirements (CWR), thereby facilitating the efficient scheduling of irrigation (Soomro et al., 2023).

2.3 Data requirement

The CROPWAT model requires three data on climate, crops, and soil. The Iraqi Ministry of Agriculture website was the source of crop and climate data in the study for the year 2022 (Iraqi Ministry of Agriculture, 2025). The climatic variables include five criteria: minimum (Tmin) and maximum (Tmax) temperatures, amount of rainfall, duration of sunshine, wind

velocity, and relative humidity, where monthly climatic data from the Climate 2.0 database was used in the CROPWAT program, and irrigation requirements for various crops were calculated at numerous weather stations worldwide. The soil type of the study area was determined as black clay (Ewaid et al., 2019).

2.4 Reference evapotranspiration

The total amount of water lost through plant transpiration and soil surface evaporation is known as evapotranspiration. Reference crop evapotranspiration, denoted Eto, is estimated from a "reference surface." The reference surface has an albedo of 0.23, a height of 0.12 m, and a constant surface resistance of 70 cm/m. It is a hypothetical reference grass crop. The reference surface is very similar to a large piece of uniformly high, well-irrigated, green grass that is actively growing and totally shadowing the ground. Approximately weekly irrigation results in a moderately dry soil surface, as shown by a consistent surface resistance of 70 cm/m, as demonstrated in equation 1 (Hussain et al., 2023a).

$$\lambda \, \mathrm{ET} \frac{= \Delta(\mathrm{Rn} - \mathrm{G}) + \mathrm{Pa}\, \mathrm{Cp}(\mathrm{es} - \mathrm{ea})/\mathrm{ra}}{\Delta + \gamma(1 + \mathrm{rsra})} \quad (1)$$

Actual rainfall denotes the part of rainfall that is utilized by crops after calculating losses, to estimate the crop water requirement (CWR) on the basis of the surface run-off and deep seepage. The principal attributes of precipitation are its volume, frequency, and intensity, which vary both over time and across different locations. A comprehensive understanding of these three primary characteristics is crucial for optimizing their complete utilization (Clarke et al., 2001). The Penman–Monteith equation (equation 2) is as follows:

$$ET_0 = \frac{0.408\Delta(Rn-G)+\gamma\frac{900}{T+273}\, u2(es-ea)}{\Delta+\gamma(1+0.34\, u2)} \quad (2)$$

Where:
Rn=represent the net radiation.
G=means represents the soil heat flux.
es–ea=represents the vapor pressure deficit of the air.
Pa=represents air density at constant pressure.
Cp=represents the specific heat of the air.
Δ=represent the slope of the relationship between saturation vapor pressure and air temperature.
γ =represents the psychometric constant.
rs=represent the surface resistances.
ra=represents aerodynamic resistance.

2.5 Crop water requirement

This analysis employs the average annual rainfall of 2022 and the CROPWAT rainfall, which was developed from the USDA S.C. methodology. Crop evapotranspiration was used to derive the CWR, and ETc was calculated by the following equation (equation 3) (FAO, 2025).

$$ETc = Kc\ ET_0 \quad (3)$$

Kc, the crop coefficient determines the essential water allocation for the crop, thereby dictating the irrigation schedule. However, the Kc value is substantially influenced by weather factors such as air temperature (C°), wind velocity, and harvesting date. As a result, it is imperative to rectify the data (Soomro et al., 2023).

2.6 Irrigation water requirement

Irrigation water requirements are based on various factors, such as the type of crop grown, the climate, and the irrigation system used. The basic concept is that irrigation water must meet the crop's water consumption which primarily includes evapotranspiration (ET), the rate of water loss from plants and soil. This water is essential for optimal growth and production. Furthermore, the accurate estimation of irrigation water requirements by CROPWAT leads to water saving and thus helps in achieving water sustainability (Champaneri et al., 2024). The Net Irrigation Requirement (NIR) and Gross Irrigation Requirement (GIR) were determined using the CROPWAT model at 70% field efficiency The factors influencing irrigation water requirement are calculated by taking into account crop type and stage, climate, and soil type including crop coefficient, rooting depth, yield response factor, length of plant growth stages and critical depletion. The crop data for wheat, barley, and rice were obtained from the website of the Iraqi Ministry of Agriculture (2025).

The CROPWAT application can be used to calculate the root zone's daily water content using the following formula (equation 4) until the end of the day, when the root zone is depleted (Valiantzas, 2013).

$$Dr,i = Dr,i-1 - (P - ROi) - li - CRi + ETci + Dpi \quad (4)$$

where Dr,i−1 is the water content in the root zone at the end of the previous day (mm.), and Dr,i is the root zone depletion at the end of the day (mm.). On day I, Pi represents the precipitation (mm.), ROi represents the surface soil runoff (mm.), and Ii represents the net irrigation depth that penetrates the soil (mm.), Cri represents the capillary rise from the groundwater table (mm.), ETci represents the crop evapotranspiration (mm.), and DPi represents the water lost in the root zone on day I (mm.).

3. Results and Discussion

3.1 Reference evapotranspiration

As illustrated in Table 1 and Figure 2, the evapotranspiration results for Al-Qadisiyah Governorate district revealed a peak in July (2.83 mm/day), which dropped to 0.82 mm/day in January. A high evapotranspiration number signifies elevated evaporation due to elevated temperatures and maximum sunlight hours. Conversely, a low evapotranspiration value was likely due to lower temperatures, indicating lower crop water requirements (Agrawal et al, 2023). Evapotranspiration is intimately connected with the length and intensity of solar radiation. Ewaid et al. (2019), in their examination of specific crops in southern Iraq, revealed that the evaporation rate increased during summer. It was clear that the combination of increasing temperatures and low humidity caused this. Moreover, the opposite was noted in winter.

Table 1. Reference evapotranspiration of the study area

Month	Min Temp. (°C)	Max Temp. (°C)	Humidity (%)	Wind (km/day)	Sun (hours)	Rad (MJ/m²/day)	ETo (mm/day)
January	5.10	18.1	67	2	0.8	5.8	0.82
February	8.4	22.5	61	2	0.9	7.2	1.07
March	9.9	24.1	50	2	1.1	9.1	1.39
April	16.8	33.5	43	2	1.3	11	1.97
May	21	36.6	35	2	1.4	12.1	2.37
June	24.5	43.5	27	2	1.7	12.8	2.69
July	26.6	44.5	29	3	1.8	12.8	2.83
August	28.8	45.3	29	2	1.6	11.7	2.71
September	23.4	42.7	31	2	1.5	10.2	2.36
October	20	37	42	2	1.1	7.9	1.86
November	14.4	27.4	55	2	0.8	6.1	1.31
December	10.2	21.2	65	2	0.7	5.3	0.98
Average	17.4	33	45	2	1.2	9.3	1.87

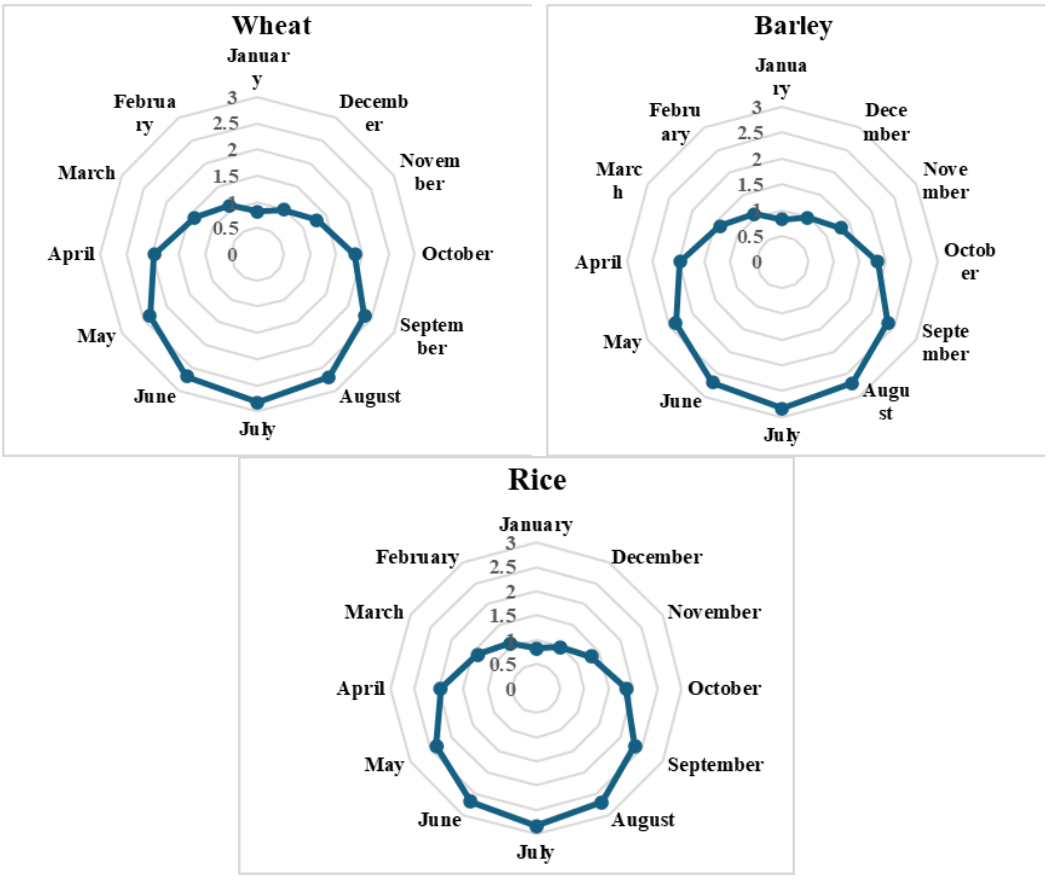


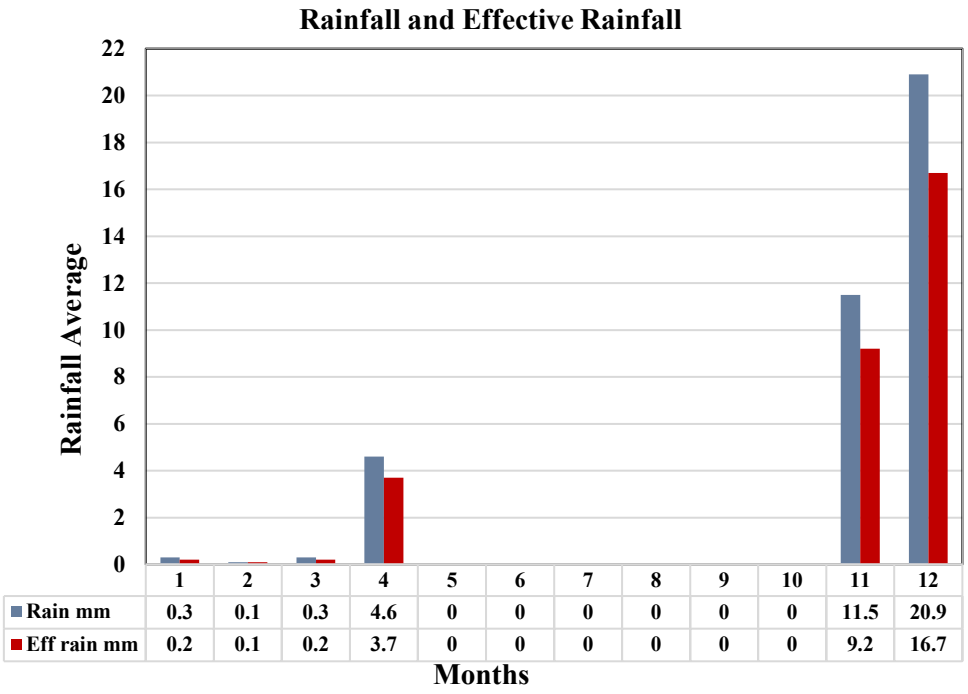
Figure 2. Illustrates the reference evapotranspiration of wheat, barley, and rice crops

3.2 Effective rainfall

Figure 3 and Tables 2, 3 and 4 show the effective rainfall values for wheat, barley, and rice were 23.2%, 26.3 %, and 0%, respectively. The main features of rainfall values for crops were different temporally, which increased in winter and in contrast to other seasons (Zhu et al., 2025).

3.3. Crop water requirement

The crop's water needs pertain to crops cultivated under optimal conditions, which are characterized by uniformity, vigorous growth, total ground coverage, absence of diseases, and favorable soil conditions, including fertility and moisture. In this setting, the crop attains its maximum production capacity.



	1	2	3	4	5	6	7	8	9	10	11	12
Rain mm	0.3	0.1	0.3	4.6	0	0	0	0	0	0	11.5	20.9
Eff rain mm	0.2	0.1	0.2	3.7	0	0	0	0	0	0	9.2	16.7

Figure 3. The monthly average rainfall and effective rainfall for the study area

Tables 2, 3, and 4 illustrate the CWR for wheat, barley, and rice in Al-Qadisiyah area of Iraq, calculated by the CROPWAT. The crop water requirements for wheat, barley, and rice in the research area were 99.1 mm, 103.4 mm, and 404.1 mm, respectively. The data indicates that the irrigation needs for rice (summer crops) were greater compared to other seasonal crops, such as wheat and barley. The data presented in Tables 2, 3, and 4 indicate that crops cultivated during the hot season necessitate increased water, which was negatively connected with reduced rainfall and positively with elevated Etc. Conversely, in the cold season, heavy rainfall corresponds with decreased ETc.

Table 2. Crop water requirements for wheat

Month	Decade	Stage	Kc (coeff)	Etc (mm/day)	Etc (mm/dec)	Eff rain (mm/dec)	Irr. Req. (mm/dec)
November	2	Init	0.3	0.39	2.4	1.9	0.8
November	3	Init	0.3	0.36	3.6	3.9	0
December	1	Init	0.3	0.33	3.3	5.5	0
December	2	Deve	0.36	0.35	3.5	6.7	0
December	3	Deve	0.62	0.58	6.3	4.5	1.9
January	1	Deve	0.9	0.79	7.9	0.3	7.6
January	2	Mid	1.1	0.9	9	0	9
January	3	Mid	1.1	1	11	0	11
February	1	Mid	1.1	1.09	10.9	0	10.9
February	2	Mid	1.1	1.18	11.8	0	11.8
February	3	Late	1.03	1.22	9.7	0	9.7
March	1	Late	0.8	1.02	10.2	0	10.2
March	2	Late	0.53	0.73	7.3	0	7.3
March	3	Late	0.34	0.54	2.2	0.1	2
					99.1	23	82.1

Table 3. Crop water requirements for barley

Month	Decade	Stage	Kc (coeff)	Etc (mm/day)	Etc (mm/dec)	Eff rain (mm/dec)	Irr. Req. (mm/dec)
October	2	Init	0.3	0.56	3.3	0	3.3
October	3	Deve	0.31	0.52	5.7	0.1	5.6
November	1	Deve	0.54	0.8	8	2.1	5.9
November	2	Deve	0.85	1.11	11.1	3.1	8
November	3	Mid	1.08	1.29	12.9	3.9	9
December	1	Mid	1.09	1.18	11.8	5.5	6.4
December	2	Mid	1.09	1.06	10.6	6.7	4
December	3	Mid	1.09	1.01	11.1	4.5	6.6
January	1	Mid	1.09	0.95	9.5	0.3	9.2
January	2	Late	0.99	0.81	8.1	0	8.1
January	3	Late	0.7	0.63	6.9	0	6.9
February	1	Late	0.4	0.4	4	0	3.9
February	2	Late	0.25	0.27	0.3	0	0.3
					103.4	26.3	77.1

Table 4. Crop water requirements for rice

Month	Decade	Stage	Kc (coeff)	Etc (mm/day)	Etc (mm/dec)	Eff rain (mm/dec)	Irr. Req. (mm/dec)
May	3	LandPrep	1.05	2.6	28.6	0	119.6
June	1	Init	1.06	2.73	27.3	0	173.6
June	2	Init	1.1	2.96	29.6	0	29.6
June	3	Deve	1.1	3.01	30.1	0	30.1
July	1	Deve	1.11	3.1	31	0	31
July	2	Deve	1.13	3.21	32.1	0	32.1
July	3	Mid	1.15	3.22	35.4	0	35.4
August	1	Mid	1.16	3.19	31.9	0	31.9
August	2	Mid	1.16	3.15	31.5	0	31.5
August	3	Mid	1.16	3.01	33.1	0	33.1
September	1	Late	1.16	2.87	28.7	0	28.7
September	2	Late	1.12	2.65	26.5	0	26.5
September	3	Late	1.07	2.36	23.6	0	23.6
October	1	Late	1.04	2.1	14.7	0	14.7
					404.1	0	641.4

The report of FAO (2025) indicates that crops receiving higher rainfall use less irrigation compared to those in areas with limited rainfall. Water requirements for crops are contingent upon (1) climate: arid and sunny conditions necessitate greater daily water intake compared to overcast and cooler climates; (2) crop species; and (3) the developmental stage of the crop: mature crops use more water than newly planted ones (Soomro et al., 2023). Our findings were supported by a study on some crops (barley, maize, potato, soybean, and millet) conducted by Saeed et al. (2021) in northern Iraq. Hussain et al. (2023b) ascertained the water requirements of several crops, such as wheat, and the results corroborate our conclusions.

3.4 Irrigation scheduling of crops

Much of Iraq's land experiences significant water loss due to inadequately maintained water distribution infrastructure, either from infiltration, flow, or leakage (Ewaid et al., 2021). Irrigation schedules help farmers to optimize crop growth according to the available quantities of water in the area crops, and the timing of its delivery. Therefore, these schedules facilitate sustainable agricultural development.

This study demonstrated that the irrigation requirements for each crop were reduced during the initial stage and then rose during the developmental period. Furthermore, irrigation requirements remained rather stable, peaking during the intermediate phase, while declining in the later phase due to the necessity for dry land to enable harvesting. Tables 5, 6 and 7 and Figures 4, 5 and 6 indicated that the rice irrigation schedules were more frequent than the other two crops due to a lack of rain during the planting season in summer. Understanding irrigation enhances field management by regulating the quantity, time, and irrigation rate in an effective and systematic manner.

Table 5. Irrigation schedules for wheat

Date	Day	Stage	Rain (mm)	Ks (fract.)	Eta (%)	Depl (%)	Net Irr (mm)	Deficit (mm)	Loss (mm)	Gr. Irr (mm)	Flow (l/s/ha)
04-May	171	Mid	0	1	100	55	165.9	0	0	237	0.16
12-Jul	End	End	0	1	100	53					

Table 6. Irrigation schedules for barley

Date	Day	Stage	Rain (mm)	Ks (fract.)	Eta (%)	Depl (%)	Net Irr (mm)	Deficit (mm)	Loss (mm)	Gr. Irr (mm)	Flow (l/s/ha)
11-Feb	End	End	0	1	100	32					

Table 7. Irrigation schedules for rice

Date	Day	Stage	Rain	Ks	Eta	Puddl	Percol.	Depl.SM	Net Gift	Loss	Depl.SAT
			mm	frac.	%	state	mm	mm	mm	mm	mm
21-May	-19	PrePu	0	0.9	90	Prep	0	41	90.8	0	40
5-Jun	-4	Puddl	0	1	100	Prep	0	9	90	0	40
8-Jun	-1	Puddl	0	1	100	OK	7.7	0	56.3	0	6.3
16-Jun	7	Init	0	1	100	OK	3.1	0	99.8	0	-0.2
2-Jul	23	Dev	0	1	100	OK	3.1	0	97.8	0	-2.2
18-Jul	39	Dev	0	1	100	OK	3.1	0	100.1	0	0.1
3-Aug	55	Mid	0	1	100	OK	3.1	0	101	0	1
19-Aug	71	Mid	0	1	100	OK	3.1	0	100.3	0	0.3
4-Sep	87	Mid	0	1	100	OK	3.1	0	97.4	0	-2.6
21-Sep	104	End	0	1	100	OK	3.1	0	98.8	0	-1.2
7-Oct	End	End	0	1	0	OK	0	0			

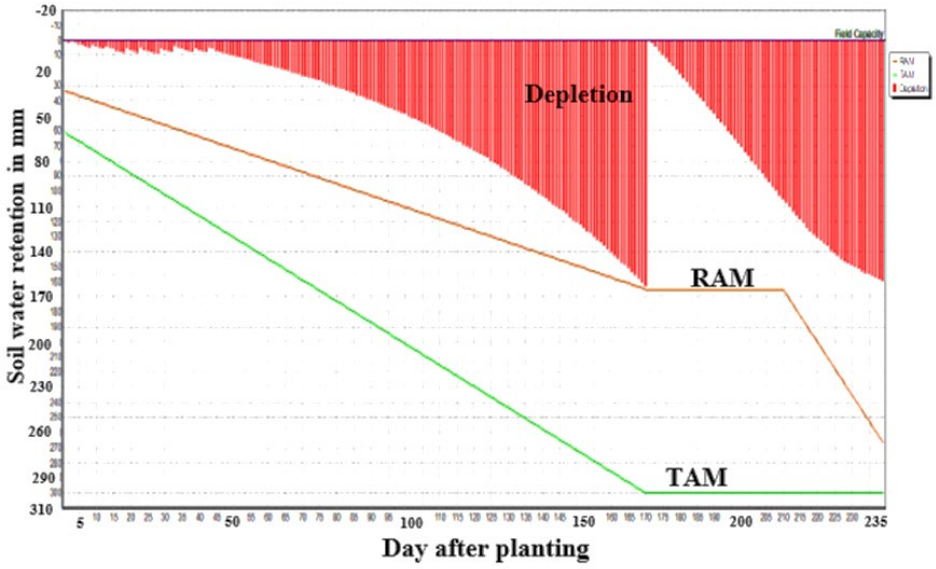


Figure 4. Irrigation schedules for wheat

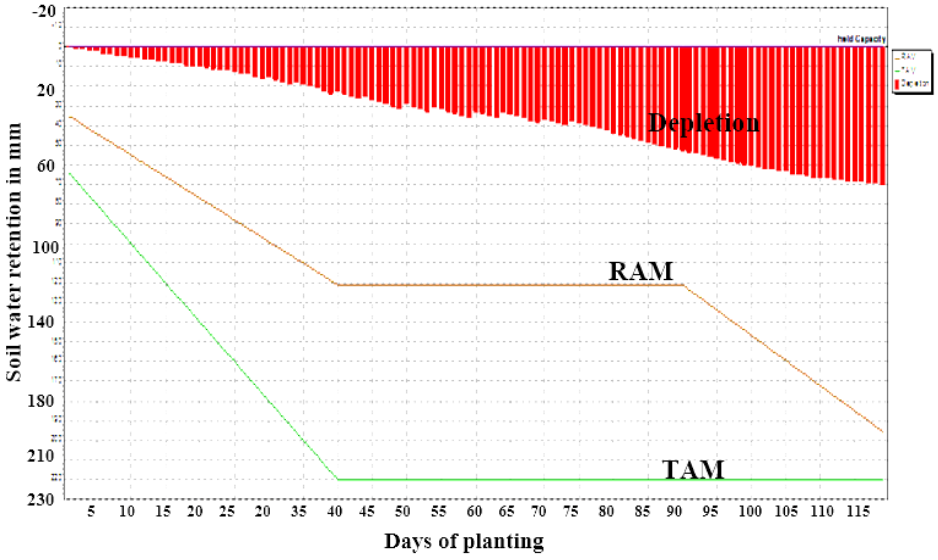


Figure 5. Irrigation schedules for barley

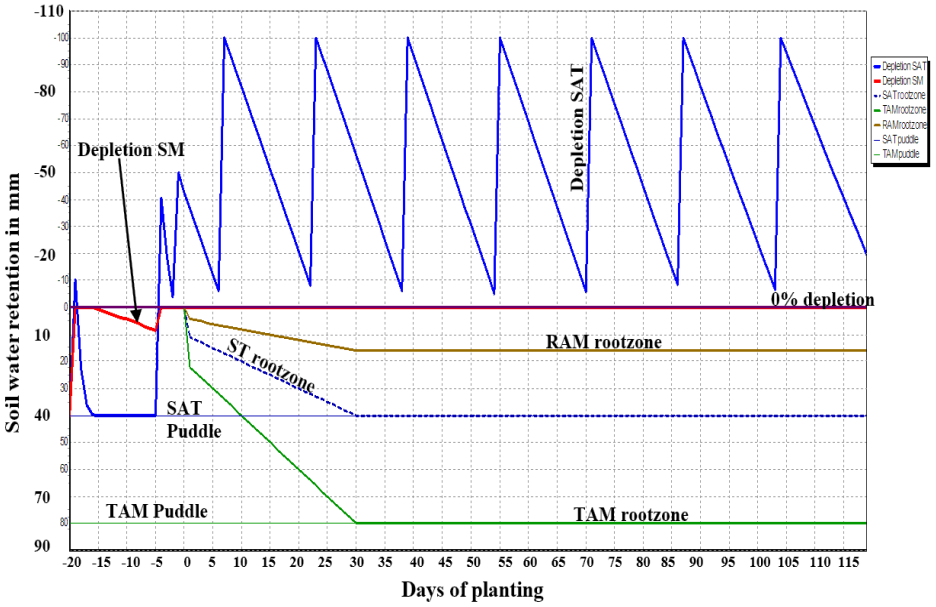


Figure 6. Irrigation schedules for rice

4. Conclusions

Our investigation, which employed the FAO CROPWAT 8.0 model, indicated that the quantity of the crop irrigation requirement for rice (summer crop) was higher than in other seasonal crops, like wheat and barley. This study indicates crops grown in the hot season required augmented water, which was adversely correlated with diminished rainfall and positively correlated with heightened Etc. In contrast, during the cold season, substantial precipitation was associated with reduced Etc. The study developed ideal irrigation schedules for wheat, barley, and rice crops, using the FAO CROPWAT program. It is expected to save irrigation water by providing accurate irrigation schedules that reduce water waste and thus would address water scarcity. The study demonstrated that irrigation demand for any crop was reduced during the initial phase and subsequently escalated during the growth phase. Furthermore, it remained rather stable, peaking during the mid-phase, while declining in the late phase due to the necessity of dry conditions for efficient harvesting. The study's results suggested that rice required more frequent watering than the other two crops due to a lack of rainfall during the planting season. The study recommended the use of CROPWAT and CLIMWAT as effective scientific tools to assess crop water requirement, irrigation water requirements, and to improve the accuracy of irrigation scheduling for farmers in Iraq and worldwide, enabling a high level of water conservation.

5. Authors' Contributions

Idrees A. Al-Bahathy designed the research, conducted the measurements, and wrote the draft; Sahar. F. Saadoun contributed to the analysis of results; Hawraa Neamah Hussein analyzed the data and reviewed the final draft; Zahraa Zahraw Al-Janabi coordinated the research and reviewed the final draft.

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6. Conflicts of Interest

All authors declared there are no conflicts of interest

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