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Estimating the Climate Water Budget and Water Consumption of the Wheat Crop in Salah Al-Din Governorate for the Period 1990-2022

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Abstract: This study utilizes Community Water Model - CWatM to calculate reference evapotranspiration and estimate the climate water budget using field data and remote sensing data obtained from three different stations in For Salah ad-Din Governorate in Iraq. The evapotranspiration calculation in CWatM is based on the FAO method, which necessitates input data that obtained from climate stations as well as the utilization of satellite images and remote sensing technology. The results showed obvious a pronounced deficit at Tikrit and Touz stations during the wheat growing season as well as high water consumption. Conversely, the Baiji station showed a water surplus during winter season across all years except for 1994, which exhibited a water deficit. During the spring season, Baiji station consistently records a water deficit.

Furthermore, there is a noticeable decrease in water consumption during the wheat growing season at Baiji compared to Tikrit and Touz stations, indicating a shift of suitable regions for wheat cultivation towards the north of the study area. The Evapotranspiration record showed a general trend towards decrease, with February being the highest for consecutive negative changes for all three stations.

As for water consumption, a general trend towards decrease was recorded during most of the growth season months, including February for both Baiji and Tuz stations, respectively. However, Tikrit station recorded the lowest directional coefficient in January. Regarding positive changes, both evaporation/production and water consumption showed a trend towards increase due to rising temperatures during April for all three stations consecutively. Meanwhile, the CWB recorded May as having the highest positive change across all study stations.

Keywords: Climate, Water budget, Wheat Crop, Water consumption, Salah Al-Din Governorate.

HIGHLIGHTS:

- Utilized CWatM to analyze climate water budget and water consumption in three stations in Iraq.

- Implemented FAO method for evapotranspiration calculation with field and remote sensing data.
- Significant water deficits were identified at Tikrit and Touz stations during the wheat growing season.
- A surplus was observed at Baiji Station during the winter season and a persistent deficit during spring season.
- Highlighted shift in suitable wheat cultivation regions towards the north of the study area.

INTRODUCTION

Climate is considered one of the most important components of the natural environment and with a large effect on the other components such as vegetation, geomorphologic features, and soil. Also, water is considered one of the most important natural resources (Delle Rose, 2023). With population growth and economic progress, water demand is expected to increase significantly in the future, in Iraq and especially in the study area (Tramblay, 2020). Climate change is expected to alter precipitation patterns and temperatures, affecting local water availability. Under the impact of both socio-economic development and climate change, the water crisis has become a burning problem worldwide (Fereres and Soriano, 2006). Although water is a sustainable resource, access to it varies both spatially and temporally, and the gap between growing demand and limited water resources is increasing (Elliott, et al., 2014). Iraq's climate is semi-arid, but until a few decades ago, the country was water-rich (Al-Ansari, 2014).

Climate change increases water demand, and the construction of multiple dams on the Euphrates and Tigris rivers in Turkey, Syria, and Iran has caused water shortages downstream. Now, there is a need for a reduction in consumption, good planning of water resources and to determine the water needs of the main crops (Ewaid, 2018).

Meteorological characteristics such as solar radiation, air temperature, humidity, and wind speed critically affect evaporation and transpiration processes (Falalakis, 2020). Crop characteristics such as type, variety, and developmental stage also influence the estimation of evaporation and transpiration. Environmental conditions such as soil salinity and fertilizer use are factors affecting evaporation and transpiration processes. Studying evaporation and transpiration is of great importance in understanding crop water needs and improving irrigation strategies and water management in agriculture (Su, Y., et al., 2023). It also helps guide agricultural policies to maximize the utilization of available water resources (Hassan2022).

Land suitable for agriculture in Iraq represents less than 15% of the country's total area, and only 4 to 5 million hectares of the 8 million available hectares are cultivated (Adamo et al., 2018). In the past, irrigation water resources in Iraq have not been managed efficiently. However, this did not pose major problems due to the abundant water supply, although it did rely on the Euphrates and Tigris rivers and adequate rainfall. Now, with the water scarcity crisis, increasing salinity, low rainfall and decreasing river flow, irrigation systems need to be improved to solve water problems (Rahi and Halihan, 2018; Ewaid, 2017 and Ewaid et al., 2018). These problems are likely to become even more prominent in the future as supply is at 43 billion cubic meters (BCM) in 2015 and is expected to be 17.6 BCM in 2025, while current demand is in the range of between 66.8 and 77 BCM (Al-Ansari, et al., 2018).

The importance of this study lies in estimating the water requirements for wheat cultivation and water availability regarding climate change and economic growth. To achieve this goal, the Community Water Model (CWatM) will be used in this study. CWatM is a hydrological model simulating the water cycle on both global and local scales, historically and in the future. Also, CWatM estimates water availability, needs, and environmental requirements, including water management and human impact within the water cycle. Through CWatM, the reference evapotranspiration (ETO) will be estimated for three stations, namely Baiji, Tikrit, and Touz using the FAO method, relying on field data, satellite imagery, actual evapotranspiration, and estimation of climatic water balance (Allen1994; Jensen, 2016; Turky, 2020; Bouregaa, 2023; Delgado-Ramírez 2023). This contributes to a better understanding of changes in water availability and their impact on the environment and the economy (Shareef, 2022). Previous studies did not reach the conclusions we arrived at in this research. Al-Hamdani's study (2020), which addressed the impact of climate change on the hydrological balance in Salah ad Din Province and studied four stations (Baiji, Tikrit, Samarra, Tuz) for the period (1981-2015) using the FAO equation, concluded the existence of a significant water deficit at all stations. Al-Jubouri (2022) focused on determining the water needs of wheat and barley crops in Najaf Governorate, identifying water losses, whether field or conveyance losses, and the efficiency of irrigation and water balance using equations (Kridel, Kharoufa, Penman).

Through the application of evapotranspiration equations to determine the water balance, it became evident that the study area suffers from a constant water deficit The importance of the study lies in this idea because the CWatM model, a hydrological model that simulates the water cycle daily on both the global and local levels, has not been comprehensively studied in terms of spatial and temporal dimensions and the mechanisms used, nor has it been brought into scientific existence. Previous studies did not extensively and comprehensively investigate the effects of climate change on water consumption and hydrological balance in Salah al Din Province to the extent and detail stipulated by this study. Therefore, it will constitute a qualitative addition to the climatic geography library in Iraq Understanding the hydrological and evapotranspiration balance is crucial for estimating the water needs of wheat crops, considering that Salah ad Din is the second largest province for wheat cultivation in Iraq. This is one of the most important steps that aid in optimal agricultural planning, achieving food security, and sustainable development.

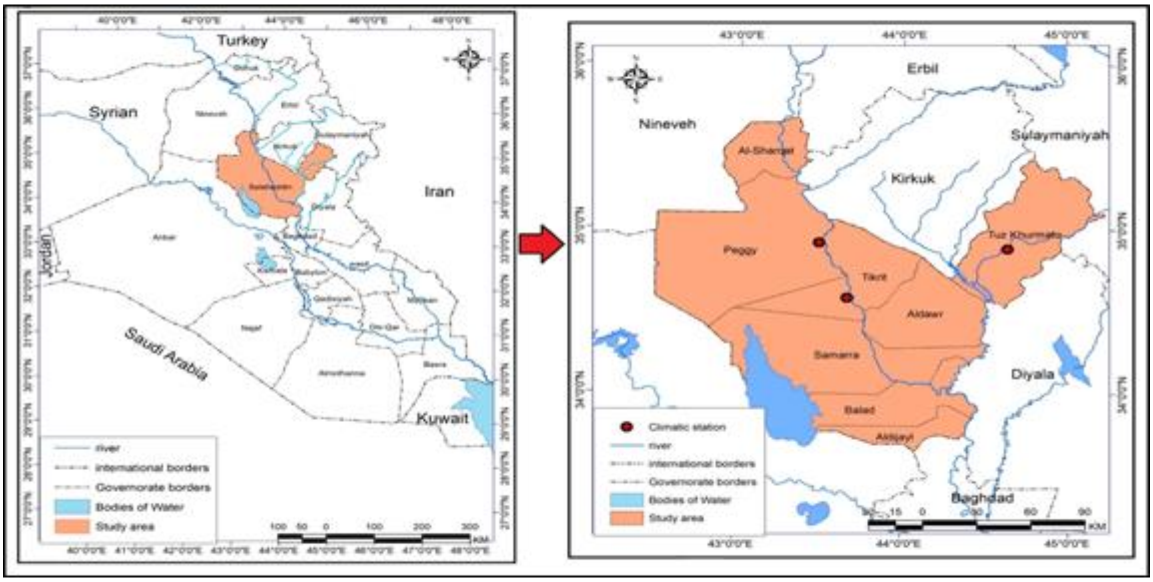

Fig. (1): Map of the study area and geographical location of the stations

THE STUDY AREA

Salah ad Din Province in Iraq is situated between longitude ((45º 10' 00" to 42º 30' 00" E)) and latitude ((35º 40' 00" to 33º 40' 00" N)). It is characterized by a cold, rainy climate in winter and a hot, dry climate in summer. Rainfall varies depending on the terrain; it increases towards the north and decreases as we move southward. Due to the availability of all the necessary components for wheat cultivation including climate, soil, and rainfall, Salah ad Din Province is considered the second largest province for wheat cultivation in Iraq. The cultivated wheat area in 2022 was approximately 1,169,135 dunams with a productivity of 850 kg, (Table 1).

Table 1: Station names and their numbers and coordinates

COD	STATION	Longitude	Latitude	Elevation /m
631	Baiji	$43^0\ 32^/$	$34^0\ 54^/$	115.5
632	Tuz	$44^0\ 39^/$	$34^0\ 53^/$	220.0
633	Tikrit	$43^0\ 42^/$	$34^0\ 34^/$	107.0

DATASET DESCRIPTION

1. Remote sensing-based data

The revolution in technology that we witness nowadays makes it easy to find relevant information anywhere in the world. Among these technologies are remote sensing applications, which have the ability to provide information related to various land surface variables. Remote sensing can cover large areas and provide high temporal resolution information accessible to users worldwide. Moreover, several products have been developed based on remote sensing data, such as reanalysis products that assimilate remote sensing data sets into land surface models, offering spatiotemporally continuous coverage of certain land surface variables. ERA5-Land is considered a promising reanalysis data set that provides several land surface variables at a fine resolution of around 9 km. The dataset covers the period from 1950 to the present and is provided at an hourly temporal resolution. ERA5-Land is based on the H-TESSEL model, which is used to generate the product of this dataset.

In this study, several land surface variables of ERA5-Land have been utilized, including surface pressure (SP), surface solar radiation downwards (SSRD), and surface thermal radiation downwards (STRD). Firstly, an extent covering the entire study area was created to mask the specific region for downloading SP, SSRD, and STRD. Secondly, the Spyder platform, a free and open-source scientific environment written in Python, was employed to facilitate the downloading of these variables, covering the entire study area and period. Finally, a MATLAB code was developed to extract point data of the three variables SP, SSRD, and STRD from the ERA5-Land data throughout the study period. The developed code opens each image and extracts the variables, saving the extracted values for corresponding dates in an Excel file. The ERA5-Land data were downloaded from the website https://cds.climate.copernicus.eu.

2. The Iraqi Ministry of Transportation, the General Authority for Meteorology and Seismology, and the NASA website (https://power.larc.nasa.gov/data-access-viewer). In this study, data on maximum temperature, minimum temperature, and wind speed were obtained from the Iraqi Ministry of Transportation, the General Authority for Meteorology and Seismology, and the NASA website to complete the missing data in the study area. The region experienced events related to ISIS terrorism, which led to the cessation of operation of meteorological stations from 2014 to 2021. So, the researchers resorted to compensating for the missing data from the mentioned sources. The climatic data used in this study has been subjected to quality control, reconstruction and homogeneity procedures recommended by WMO.

3. During the study period from 1990 to 2022, the researchers selected specific years by dividing the time series of annual rainfall totals into four periods: 1990-2000, 2000-2010, 2010-2020, and 2020-2022. They then calculated the average annual rainfall totals for each ten-year period and chose the year closest to the average annual rainfall total to represent the general condition. For the month of November, it has been added to the winter season because the growth season starts from November 15th, and therefore 15 days cannot be considered as one season.

METHODS

In this study, the FAO equation was employed to calculate the reference evapotranspiration (ET0) at the three stations. To derive ET0 estimations at these specific locations, a custom

MATLAB code for patch processing was developed. This code was designed to generate ET0 estimations at the designated stations utilizing a methodology akin to that utilized in the CWatM (Catchment Water Management) model.

Following the approach adopted by CWatM, our study applied similar steps to calculate ET0 utilizing MATLAB. The developed code possesses the capability to extract pertinent data from raster datasets, where each variable is represented by a raster image encompassing the entire study area. Subsequently, the code implements the FAO equation to compute ET0 estimations, which are then saved into an Excel file. This streamlined process facilitates ease of analysis and enhances the usability of the generated ET0 data for further investigations and modeling exercises. It effectively explains the relationship between crop evapotranspiration (ETc) and reference evapotranspiration (ETo) using the equation (ETc = Kc * ETo), which was used in the research to calculate water consumption for wheat crops in different study areas. Therefore, in this chapter, we will rely on the use of the general trend method, the annual rate of change, and the change during the study period to clarify the changes occurring in the rainfall component in the study area. The main goal is to study the behavior and trend of phenomena in the past for the purpose of obtaining a realistic perception and developing an appropriate model that describes the pattern of the series. which is time, and the other is the response variable (the value of the phenomenon studied), and it can be expressed mathematically as follows (Al-Shaarawy, 2005).

Y= f (t)

Where:

Y = Trend

f = phenomena

t =Time

1. Secular Trend The general trend in time series is defined as the upward and downward movements in the series level over the long term and is usually known as long-term variations. The general trend is the outcome or result of the influence of a group of independent factors that affected the phenomenon over time.

2. Extract the annual rate of change through the following equation (Abu Zeid, 2010).

C=(pi/y) *100

Where;

C = Annual rate of change

Pi = Direction coefficient

Y= Average

RESULTS AND DISCUSSION

1. Estimating water consumption and climatic water balance for wheat crops at Baiji station.

It was clear from this study, for the month of November, the years (1994, 2007, 2013, 2022) exhibited variations between the lowest recorded water deficit (-2.0 mm) in 1994 and the highest surplus (26.7 mm) in 2013. As for the crop coefficient (KC), it remained constant at 0.35 for all years (1994, 2007, 2013, 2022) due to the crop's initial growth stage requiring minimal water (See Table 2 and Figure 1).

In December month, the years (1994, 2007, 2013, 2022) showed differences between the lowest water deficit (-11.1 mm) in 1994 and the highest surplus (15.4 mm) in 2013. The reference evapotranspiration (ETc) varied between years, ranging from the lowest value of 8.01 mm in 2007 to the highest value of 31.75 mm in 1994. (Table 2 and Figure 1).

In January month, the years (1994, 2007, 2013, 2022) experienced water surpluses, ranging from 12.9 mm in 1994 to 28.4 mm in 2013. The ETc varied between years, with the lowest value recorded at 16.23 mm in 2007 and the highest at 26.62 mm in 2013 (Table 2 and Figure 1).

February month saw variations between water surplus and deficit, with the lowest deficit (-39.5 mm) in 2013 and the highest surplus (2.6 mm) in 2007. The ETc ranged from 41.54 mm in 2007 to 80.63 mm in 1994. The crop coefficient (KC) reached 0.75 (Table 2 and Figure 1).

March month exhibited water deficits, ranging from -90.0 mm in 2007 to -152.2 mm in 1994. The ETc varied between the lowest value of 97.89 mm in 2007 and the highest of 174.20 mm in 1994. The KC was 1.20. In April, water deficits varied between -140.1 mm in 2007 and -238.0 mm in 1994. ETc ranged from 162.63 mm in 2007 to 247.98 mm in 1994. The KC was 1.10. May month showed water deficits, ranging from (-79.6) mm in 2007 to -230.3 mm in 1994. ETc varied between -79.6 mm in 2007 and 247.98 mm in 1994. The KC was 0.85 (Table 2 and Figure 1).

2. **Water Balance and Seasonal Water Consumption (Winter, Spring) for Wheat Crop at Beiji Station.**

The winter season (November, December, January, February) variability for the years (Beiji 1994, 2007, 2013, 2022) showed a contrast between water deficit and surplus. There was a water deficit recorded as (-14.2, -14.9) mm for the years (1994, 2022) respectively, while a water surplus was recorded as (7.1, 7.7) mm for the years (2007, 2013) respectively. As for the ETC (evapotranspiration) for the winter season, it ranged between the lowest evaporation/transpiration value at Beiji station (18.76) mm for the year 2007 and the highest value (41.43) mm (See Table 2 and Figure 1).

Regarding the spring season (March, April, May), there was a water deficit in all years amounting to (-206.8, -103.2, -141.7, -178.4) mm, respectively. The actual evapotranspiration for the spring season varied between the lowest ETC value (32.36) mm for the year 2007 and the highest ETC value (217.49) mm for the year 1994 (Table 2 and Figure 1).

Table 2: Summary of climatic Baiji station characteristic.

Year	Month	SSRD	STRD	Tmax	Tmin	R.H	Wind	SP	Reference ET0 mm/day	Kc	Etc mm/month	Rainfall mm/month	CWB mm/month
1994	NOV	12.4	25.7	20.8	10.8	77.0	1.4	100.16	2.69	0.35	28.23	26.2	-2.0
	DEC	9.1	26.3	12.6	3.1	80.0	2.1	100.47	3.02	0.35	31.75	20.7	-11.1
	JAN	10.9	25.6	16.6	6.5	84.0	1.3	100.14	2.39	0.35	25.10	38.0	12.9
	FEB	15.5	24.5	17.5	5.7	71.0	1.9	100.06	3.58	0.75	80.63	24.0	-56.6
	Winter	11.97	25.51	16.88	6.53	78.00	1.68	100.21	2.92		41.43	27.2	-14.2
	SEA	20.0	26.8	23.1	10.3	62.0	1.8	99.74	4.84	1.20	174.20	22.0	-152.2
	APR	23.8	29.6	31.8	16.7	52.0	2.5	99.47	7.51	1.10	247.98	10.0	-238.0
	MAY	27.6	30.6	36.0	20.4	36.0	2.7	99.20	9.03	0.85	230.30	0.0	-230.3
	Spring	23.80	29.00	30.30	15.80	50.00	2.33	99.47	7.13		217.49	10.7	-206.8
2007	NOV	13.2	25.2	23.4	8.3	54.0	0.3	100.16	0.88	0.35	9.26	1.0	-8.3
	Dec	10.8	23.2	15.7	1.9	58.0	0.4	100.45	0.76	0.35	8.01	18.3	10.3
	JAN	11.5	23.6	14.4	1.3	66.0	0.8	100.60	1.55	0.35	16.23	39.9	23.7
	FEB	14.6	25.4	18.0	5.2	58.0	0.5	99.93	1.85	0.75	41.54	44.1	2.6
	Winter	12.54	24.37	17.85	4.18	59.00	0.50	100.28	1.26		18.76	25.8	7.1
	SEA	19.9	26.0	24.7	8.7	49.0	0.5	99.71	2.72	1.20	97.89	7.9	-90.0
	APR	23.5	28.0	28.7	14.	44.	1.2	99.4	4.93	1.1	162.63	22.5	-140.1

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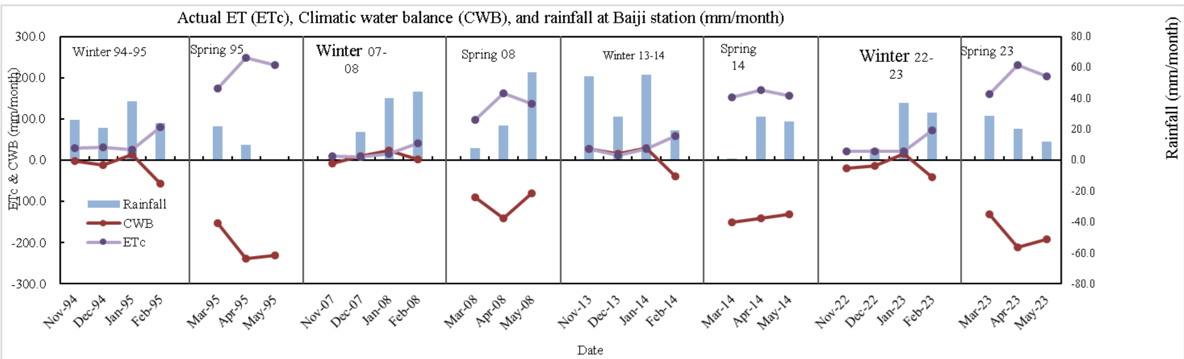
	MAY	26.0	32.8	36.3	23.5	33.0	0.7	99.15	5.36	0.85	136.56	57.0	-79.6
	Spring	23.12	28.96	29.93	15.40	42.00	0.80	99.45	4.33		132.36	29.1	-103.2
	NOV	11.4	28.8	24.1	14.4	62.5	1.1	99.99	2.63	0.35	27.57	54.3	26.7
	Dec	9.9	25.6	17.0	7.4	63.5	0.6	100.15	1.19	0.35	12.52	27.9	15.4
	JAN	11.0	24.6	13.9	4.0	85.0	1.6	100.18	2.53	0.35	26.62	55.0	28.4
	FEB	15.1	25.9	17.0	5.9	75.0	0.9	100.15	2.60	0.75	58.50	19.0	-39.5
2013	Winter	11.86	26.21	18.00	7.93	71.50	1.05	100.12	2.24		31.30	39.1	7.7
	MAR	20.4	26.4	20.6	8.6	57.0	1.4	99.76	4.24	1.20	152.61	0.9	-151.7
	APR	25.1	28.7	31.8	17.4	49.0	1.1	99.37	5.14	1.10	169.57	28.0	-141.6
	MAY	25.6	32.1	36.4	23.1	51.0	1.2	99.16	6.15	0.85	156.88	25.1	-131.8
	Spring	23.71	29.06	29.60	16.37	52.33	1.23	99.43	5.18		159.69	18.0	-141.7
	NOV	12.9	27.5	26.7	12.7	45.5	0.8	100.10	2.03	0.35	21.30	0.7	-20.6
	DEC	10.6	25.0	18.4	5.9	65.0	1.1	100.29	1.99	0.35	20.87	7.3	-13.6
	JAN	11.6	24.4	19.6	4.9	71.0	1.1	100.21	2.00	0.35	21.01	36.7	15.7
	FEB	15.5	25.5	21.0	7.3	63.0	1.3	100.03	3.19	0.75	71.78	30.7	-41.0
2022	Winter	12.65	25.61	21.43	7.70	61.13	1.10	100.16	2.30		33.74	18.9	-14.9
	MAR	19.6	25.3	24.1	10.9	59.5	1.8	99.93	4.47	1.20	161.00	28.9	-132.1
	APR	24.9	28.9	33.0	17.1	51.5	2.1	99.44	7.02	1.10	231.57	20.3	-211.3
	MAY	28.0	30.1	40.1	24.0	33.0	2.2	99.25	7.99	0.85	203.78	12.0	-191.8
	Spring	24.15	28.12	32.40	17.33	48.00	2.04	99.54	6.49		198.78	20.4	-178.4

3. Estimating water consumption and climatic water balance for wheat crop at Tikrit station.

In the month of November for the years (Tikrit) 1993, 2004, 2021, and 2013, there was a variation between the water deficit, which reached its lowest level at (-1.4) mm in 2013, and the water surplus, which reached its highest level at (29.4) mm respectively in 1993. Regarding (ETc), there was variation between years, ranging from a minimum value of (45.83) mm in 1993 to a maximum value of (54.92) mm in 2004. As for KC, its value was 0.35 for all years 1993, 2004, 2021, and 2013 (See Table 3 and Figure 2).

The month of December for the years 1993, 2004, 2021, and 2013 witnessed variation between the water deficit, which reached (-23.1) mm in 2013, and the water surplus, which reached its highest level at (45.8) mm consecutively in 2021. Regarding (ETc), there was variation between years, with the recorded range from the minimum value in 1993 (32.81 mm) to the maximum value in 2004 (36.57 mm) (Table 3 and Figure 2).



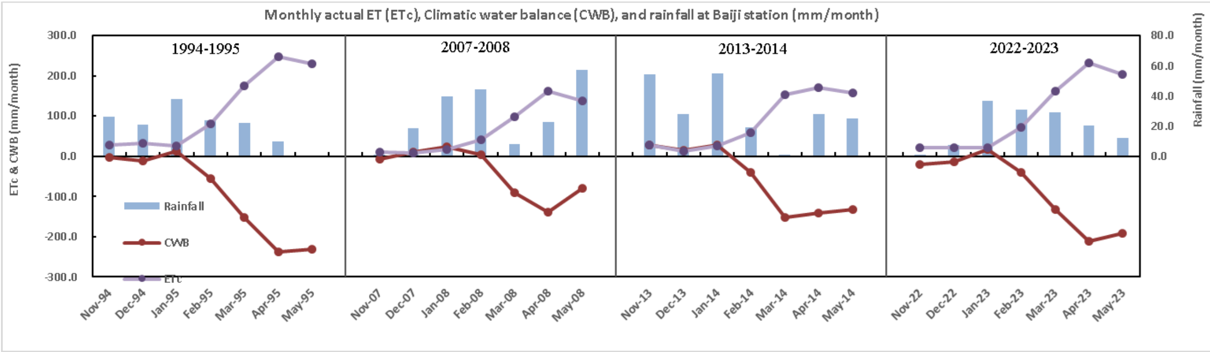


Figure 1: Evaporation/transpiration and climate water budget at Baiji station.

The month of January for the years 1993, 2004, 2021, and 2013 witnessed variation between the water deficit, which reached (-5.0) mm in 2021, and the highest water surplus recorded, which reached (13.8) mm in 2004. Regarding (ETc), there was variation between years, with the range recorded from the minimum value in 1993 (32.57 mm) to the maximum value in 2004 (40.99 mm) (Table 3 and Figure 2).

The month of February for the years 1993, 2004, 2021, and 2013 witnessed a water deficit varying between its lowest value recorded (-27.5) mm in 2021 and its highest deficit recorded (-80.2) mm in 2013. Regarding (ETc), there was variation between years, with the range recorded from the minimum value in 1993 (90.17 mm) to the maximum value in 2004 (108.81 mm) (Table3 and Figure 2).

The month of March for the years 1993, 2004, 2021, and 2013 witnessed a water deficit varying between its lowest value recorded (-173.9) mm in 2021 and its highest deficit recorded (-225.9) mm in 2004. Regarding (ETc), there was variation between years, with the range recorded from the minimum value in 2013 (194.76 mm) to the maximum value in 2004 (226.01 mm) (Table 3 and Figure 2).

The month of April for the years 1993, 2004, 2021, and 2013 witnessed a water deficit varying between its lowest value recorded (-207.9) mm in 1993 and its highest deficit recorded (-247.1) mm in 2004. Regarding (ETc), there was variation between years. (Table 3 and Figure 2).

4. Water Balance and Seasonal Water Consumption (Winter, Spring) for Wheat Crop at Tikrit Station.

Winter precipitation (November, December, January, February) for the years 1993, 2004, 2021, and 2013 varied between water deficit and water surplus. A water deficit of (-18.6, -22.9, -9.1) millimeters was recorded for the years 2004, 2021, and 2013, respectively, while a water surplus of 4.1 millimeters was recorded for the year 1993. As for the Evapotranspiration (ETC) for the winter season, it ranged from the lowest evaporation value recorded at Beiji station (51.71 mm) in 1993 to the highest value (60.32 mm) in 2004. (See Table 3 and Figure 2).

In the spring season (March, April, May), a water deficit was recorded in all years, amounting to (-219.6, -247.2, -209.9, -217.9) millimeters respectively for the years 1993, 2004, 2021, and 2013. The actual evapotranspiration (ETC) for spring ranged from the lowest value of ETC (220.30 mm) in 2013 to the highest value of ETC (253.12 mm) in 2004. (Table 3 and Figure 2).

Table 3: Summary of climatic Tikrit station characteristic.

Year	Month	SSRD	STRD	Tmax	Tmin	R.H	Wind	SP	Reference ET0 mm/day	Kc	Etc mm/day	Etc mm/month	Rainfall mm/month	CWBmm/ month
1993	NOV	11.9	26.8	19.7	9.0	64.0	2.6	100.43	4.36	0.35	1.53	45.83	75.2	29.4
	DEC	9.3	25.0	16.6	6.7	81.0	2.2	100.56	3.12	0.35	1.09	32.81	72.7	39.9
	JAN	11.4	23.9	12.8	2.6	74.0	2.3	100.63	3.10	0.35	1.09	32.57	45.8	13.2
	FEB	15.	23.	15.	4.5	66.	2.9	100.	4.25	0.	3.19	95.61	29.7	-65.9

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	Winter	11.98	24.87	16.03	5.70	71.25	2.50	100.52	3.71		1.72			
	SEA	21.0	25.1	20.9	7.6	48.0	3.0	100.13	5.84	1.20	7.00	210.14	6.8	-203.3
	APR	23.3	28.8	27.0	14.3	54.0	3.3	99.80	7.94	1.10	8.73	262.04	54.1	-207.9
	MAY	24.8	31.2	32.0	20.0	45.0	3.8	99.53	10.01	0.85	8.50	255.14	7.5	-247.6
	Spring	23.02	28.38	26.63	13.97	49.00	3.37	99.82	7.93		8.08			
	NOV	12.4	26.7	22.4	9.2	65.6	3.2	100.43	5.23	0.35	1.83	54.92	24.0	-30.9
	Dec	9.9	25.3	15.3	5.8	65.3	2.5	100.68	3.48	0.35	1.22	36.57	41.6	5.0
	JAN	10.8	25.6	14.1	4.6	81.9	2.9	100.17	3.90	0.35	1.37	40.99	54.8	13.8
	FEB	14.8	25.1	18.4	6.6	74.3	3.1	100.47	4.84	0.75	3.63	108.81	46.3	-62.5
2004	Winter	11.99	25.66	17.54	6.55	71.78	2.93	100.44	4.36		2.01			
	MAR	20.5	26.8	21.0	8.2	47.8	3.2	100.19	6.28	1.20	7.53	226.01	0.1	-225.9
	APR	24.1	28.2	25.7	13.6	41.2	3.4	99.64	7.93	1.10	8.72	261.67	14.6	-247.1
	MAY	27.2	30.6	37.4	22.4	32.5	3.7	99.30	10.65	0.85	9.06	271.67	3.1	-268.6
	Spring	23.91	28.54	28.03	14.73	40.50	3.43	99.71	8.29		8.44			
	NOV	11.6	28.9	23.7	14.1	77.0	2.2	100.20	4.42	0.35	1.55	46.40	45.0	-1.4
	Dec	10.1	25.7	17.1	7.1	66.5	2.1	100.37	3.29	0.35	1.15	34.50	11.4	-23.1
	JAN	11.1	24.7	14.4	3.3	70.0	2.7	100.41	3.63	0.35	1.27	38.08	51.1	13.0
	FEB	15.3	26.0	16.6	5.6	70.0	2.1	100.37	4.01	0.75	3.01	90.17	10.0	-80.2
2013	Winter	12.05	26.32	17.95	7.53	70.88	2.28	100.34	3.83		1.74			
	MAR	20.6	26.5	20.2	7.8	48.0	2.4	99.97	5.41	1.20	6.49	194.76	0.7	-194.1
	APR	25.2	28.8	31.8	17.1	37.0	2.4	99.58	7.43	1.10	8.17	245.18	0.0	-245.2
	MAY	25.5	32.2	36.8	23.4	43.0	2.5	99.37	8.66	0.85	7.36	220.95	30.4	-190.5
	Spring	23.79	29.14	29.60	16.10	42.67	2.43	99.64	7.17		7.34			
	NOV	13.1	28.3	25.4	12.1	45.5	2.3	100.29	4.73	0.35	1.66	49.66	0.1	-49.6
	DEC	10.7	25.3	19.8	8.2	65.0	2.0	100.67	3.23	0.35	1.13	33.92	79.7	45.8
	JAN	11.8	24.2	15.3	5.0	71.0	2.7	100.61	3.73	0.35	1.30	39.12	34.1	-5.0
	FEB	15.8	25.5	16.5	5.3	63.0	2.5	100.45	4.36	0.75	3.27	98.08	70.6	-27.5
2021	Winter	12.87	25.82	19.25	7.64	61.13	2.38	100.51	4.01		1.84			
	MAR	19.9	26.7	23.2	10.7	59.5	2.8	99.98	6.03	1.20	7.24	217.11	43.2	-173.9
	APR	25.0	29.2	27.0	14.4	51.5	2.8	99.86	7.77	1.10	8.55	256.37	28.0	-228.4
	MAY	28.1	31.6	42.2	22.2	33.0	3.0	99.20	10.18	0.85	8.66	259.69	8.3	-251.4
	Spring	24.33	29.16	30.77	15.75	48.00	2.89	99.68	7.99		8.15			

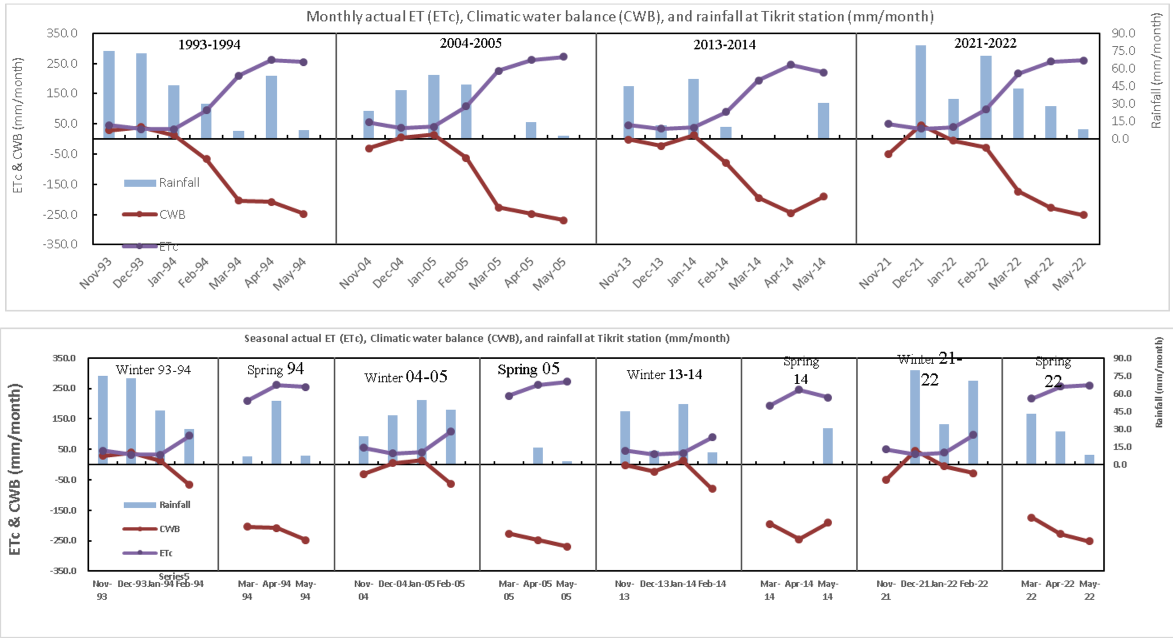

Figure 2: Evaporation/transpiration and climate water budget in Tikrit station.

5. Estimating water consumption and climatic water balance for wheat crop at Touz station.

The month of November for the years 1990, 2007, 2020, and 2014 exhibited variations between the water deficit, reaching (-11.0) millimeters in 2007, and the water surplus, peaking at (83.8) millimeters in 2014. The crop evapotranspiration (ETc) displayed variations between years, ranging from the lowest value of (31.16) millimeters in 2020 to the highest value of (35.90) millimeters in 1990 (See Table 4 and Figure 3).

Similarly, the month of December for the years 1990, 2007, 2020, and 2014 showed variations between the water deficit, which amounted to (-18.5) millimeters in 2007, and the water surplus, reaching its highest level of (53.4) millimeters in 1990. The ETc varied across years, ranging from the lowest value of (20.96) millimeters in 2007 to the highest value of (28.23) millimeters in 2020 (Table 4 and Figure 3).

- For the month of January in the years 1990, 2007, 2020, and 2014, there was a water surplus ranging from (18.8, 36.5) millimeters for the years 2007 and 2020 respectively. The ETc varied between years, ranging from the lowest value of (22.03) millimeters in 2007 to the highest value of (27.15) millimeters in 2014 (Table 4 and Figure 3).
- In February, a water deficit was recorded, with the lowest value observed in 2020 (-8.4) millimeters and the highest in 2014 (-74.6) millimeters. The ETc varied between the lowest value in 1993 (90.17) millimeters and the highest value in 2004 (108.81) millimeters (Table 4 and Figure 3).

March recorded a water deficit ranging from the lowest value of (-107.7) millimeters in 2020 to the highest value of (-157.9) millimeters in 2014. The ETc varied between the lowest value of (161.12) millimeters in 2007 and the highest value of (195.65) millimeters in 2014. April exhibited a water deficit ranging from the lowest value of (150.6) millimeters in 2007 to the highest value of (-218.2) millimeters in 2014. The ETc varied between the lowest value of (206.22) millimeters in 1990 and the highest value of (232.68) millimeters in 2014. (Table 4 and Figure 3).

May experienced a water deficit ranging from the lowest value of (-187.2) millimeters in 2014 to the highest value of (-218.6) millimeters in 1990. The ETc varied between the lowest value of (191.50) millimeters in 2014 and the highest value of (227.40) millimeters in 1990, (Table 4 and Figure 3).

6. **Water Balance and Seasonal Water Consumption (Winter, Spring) for Wheat Crop at Touz Station.**

The variations during the winter season (November, December, January, February) for the years 1990, 2007, 2020, and 2014, between water deficits and surpluses, were evident. A water deficit of (-1.1) millimeters was recorded in 2007, while water surpluses of (2.9, 20.5, 7.6) millimeters were recorded for the years 1990, 2020, and 2014, respectively. As for the crop evapotranspiration (ETc) during the winter season, it ranged from the lowest evaporation/transpiration rate recorded in 2007 (36.16 millimeters) to the highest recorded in 1990 (42.65 millimeters). (See Table 4 and Figure 3).

In contrast, during the spring season (March, April, May), water deficits were observed in all years, amounting to (-178.4, -165.8, -187.7, -169.8) millimeters respectively for the years 1990, 2007, 2020, and 2014. The actual evapotranspiration (ETc) during spring varied between the lowest value of (191.37) millimeters in 2007 and the highest value of (206.61) millimeters in 2014 (Table 4 and Figure 3).

7. **Analysis of the annual trend and change in evapotranspiration values, water consumption, and climatic water balance during the wheat growth season for stations (Baiji, Tikrit, Tuz) during the period 1990-2022.**

Through the analysis of trends and changes in evapotranspiration, water consumption, and climatic water balance during the wheat growth season for the stations (Baiji, Tuz, Tikrit), the following points emerge:

7.1 Evapotranspiration exhibited a general decreasing trend during most months of the wheat growth season, with February showing the highest variability. The trend coefficients were (-0.225, -0.193, -0.221) mm with annual changes of (-0.0043, -0.0034, -0.0040) mm for Baiji, Tuz, and Tikrit stations, respectively. Conversely, positive changes towards an increase were observed during April with trend coefficients of (0.747, 0.549, 0.649) mm and annual changes of (0.0048, 0.0021, 0.0038) mm for the three stations, respectively.

7.2 Water consumption showed a general decreasing trend during most months of the growth season, notably in February for Baiji and Tuz stations with trend coefficients of (0.334, 0.248) mm and annual changes of (0.0029, 0.0018) mm, respectively. Tikrit station recorded the lowest trend coefficient in January at (0.267) mm with an annual change of (0.0015) mm. Conversely, positive trends towards an increase in consumption were recorded in April with trend coefficients of (0.345, 0.249, 0.225) mm and annual changes of (0.0022, 0.0017, 0.0015) mm for the three stations, respectively.

7.3 Climatic Water Balance (CWB) exhibited a negative trend towards decrease, with the highest negative change recorded in February for all studied stations with trend coefficients of (-0.199, -0.221, -0.225) and annual changes of (-0.0012, -0.0018, -0.0019) mm for the three stations, respectively. May showed the highest positive change in all study stations with trend coefficients of (0.345, 0.321, 0.285) mm and annual changes of (0.0026, 0.0022, 0.0017) mm for the stations, respectively.

CONCLUSIONS

Clear water deficit was found in Tikrit and Touz stations during the wheat growing season, while Baiji station recorded a water surplus during the winter months except for 1994, and a water deficit during the spring season in all years. This is in addition to (Al-Hamdani's study, 2020), despite its reliance on the FAO equation, which addressed four stations (Baiji, Tikrit, Samarra, Tuz). It indicated a significant water deficit in all stations.

1. Water consumption decreased noticeably at Baiji station during the wheat growing season compared to an increase at Tikrit and Touz stations, this implies that there is a clear

terrestrial warming expected to occur at the Tikrit and Tuz stations in the coming years. indicating a shift of suitable wheat cultivation regions towards the north of the study area.

2. The crop growth coefficient Kc varied between 0.35 during November, December, January due to the early growth stage of the crop, and 1.20 in March due to high temperatures, high evapotranspiration, low precipitation, and increased water requirement of the crop, resulting in high water consumption.
3. The FAO Penman-Monteith method is recommended as the sole method for determining ETo in this study. This method was chosen because it closely approximates the ETo for grass at the study site, is physically based, and considers both physiological and dynamic factors. This is considered one of the most important factors for selecting the CWatM model for evapotranspiration calculation in this study, as it primarily relies on the FAO Penman-Monteith method for evapotranspiration calculation.
4. The Evapotranspiration record showed a general trend towards decrease during most of the growth season months for the wheat crop, among which February stood out as the highest for consecutive negative changes for all three stations. As for water consumption, a general trend towards decrease was recorded during most of the growth season months, including February for both Baiji and Tuz stations, respectively, while Tikrit station recorded the lowest directional coefficient in January. Regarding positive changes, both evaporation/production and water consumption showed a trend towards increase during April for all three stations consecutively. Meanwhile, the CWB recorded May as having the highest positive change across all study stations.

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