Water balance of the basin of Mandali/ east part of Iraq

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Abstract

Mandali Basin is located between latitudes (33° 39' 00" and 33° 54' 55") to the north and longitudes (45° 11' 00" and 45° 40' 00") to the east; to the east of Diyala province at the Iraqi-Iranian border; the basin area is approximately 491 km^2.

From the study of climate reality of the basin between 1990-2013and assessment of the basic climate transactions, it was found that the annual rate of rainfall is 253.02 mm, the relative humidity (44.4%), the temperature (21.3 °C), wind speed (2.08 m /sec.), sunshine (8.27 h/day) and evaporation of the basin class (a) (271.98 mm) and corrected potential evapotranspiration (80.03 mm). The results of the data analysis show that, there are three basic periods of climate variability wet period, semi wet and dry period.

This study shows that, there is water surplus of 60.87% of the rainfall amount which is equivalent to 154.03 mm, the amount of runoff is 7.47 mm, and the amount of water recharge is 146.56mm.

Keywords
Mandali Basin,
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الموازنة المائية لحوض مندلي/ شرق العراق

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الخلاصة

يقع حوض مندلي بين دائرتي عرض ("00 '39 °33 و "55 '54 °33) شمالاً وخطي طول ("00 '11 °45 و "00 '40 °45) شرقاً شرق محافظة ديالى عند الحدود العراقية-الإيرانية؛ وتبلغ مساحة الحوض حوالي (491 Km^2).

من دراسة الواقع المناخي للحوض للفترة 1990-2013 وتقييم المعاملات المناخية الأساسية حيث تبين إن المعدل السنوي للساقط المطري يبلغ (253.02mm)، والرطوبة النسبية (44.4%)، ودرجة الحرارة (21.3°C)، وسرعة الرياح (2.08 m/sec.)، والسطوع الشمسي (8.27h/day) والتبخر من الحوض صنف (أ) الأرضي (271.98 mm) والتبخر نتح الكامن المصحح (80.03 mm). وقد بينت نتائج تحاليل هذه المعطيات وجود ثلاث فترات أساسية للتغاير المناخي وهي فترة رطبة وشبه رطبة وجافة.

وأظهرت الدراسة وجود زيادة مائية بنسبة (60.87%) من كمية الساقط المطري أي ما يعادل (154.034mm)، ومقدار الجريان السطحي (7.47mm)، ومقدار تغذية المياه الجوفية (146.56 mm).

Introduction

Mandali Basin is located between latitudes (33° 54" 55'- 33° 39" 00') to the north and longitudes (45° 40" 00′ - 45° 11" 00′) to the east; to the east of Diyala province, at the Iraqi-Iranian border; the basin area is approximately (491 km^2). Fig.1 it can be seen that, the rock exposures in the basin extends from the age (Pliocene-Recent) which is represented by Euphrates, Fetha (lower Fars), Anjana (upper Fars) and Muqdadiyah and Bai Hassan as well as the deposits of Quaternary [1].

Study area

Structurally the study area is located within the central eastern part of the Mesopotamian plain and at the southwestern part of the foothill [1]. Region containing some of the geomorphological phenomena of the basin, which is the hills, plains and valleys, as, characterized by the presence of the parallel and dendritic drainage patterns [2]. The area is represented as a good agricultural land where pomegranate orchards and palm are present with cultivation of seasonal crops, wheat and barley. Also famous for herding sheep and cows are a better area in Iraq.

The study of climatic elements in hydrogeological studies is aimed to calculate the water balance of the groundwater. One of the climate factors which affects the calculating is that the amount and intensity of rainfall, the spread of the fallen and the relative humidity, which is considered as one of the water availability elements in the region. While the temperature, sunshine, wind speed and evaporation of the basin class (a) and the potential evapotranspiration basic elements of water loss. Atlas has to take advantage of Iraq's climate and climate information recorded in the stations Badra (Ba) and Khanaqin (Ka) for the period (1990-2013) and through the monthly averages of climate elements account for the Mandali.

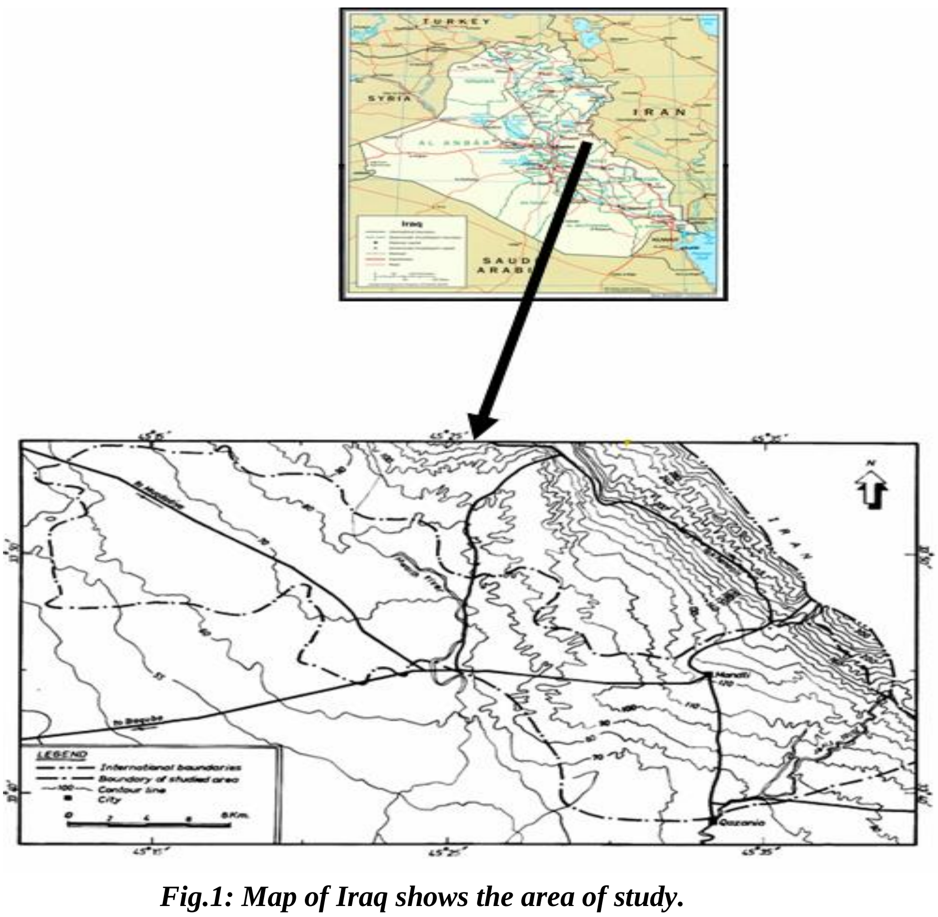

Fig.1: Map of Iraq shows the area of study.

Table 1: Monthly averages for the various stations of Khanaqin climatic elements (Ka) and Badra (Ba) for the period from (1990 – 2013) [3].

Months	Rainfall(mm)		R.H.%		Temperature (°C)		Wind Speed(m/sec)		S.SH.(h./day)		Evaporation (mm)	
	Ka	Ba	Ka	Ba	Ka	Ba	Ka	Ba	Ka	Ba	Ka	Ba
Oct.	17.2	16.11	39.94	34.2	25.2	26.7	1.18	2.37	7.5	8.5	276.45	233.38
Nov.	64.8	36.05	60.9	56.4	16.9	18.41	0.94	2.01	6.66	7.08	127.98	111.95
Dec.	51.86	32.25	71.1	67.05	11.8	12.81	0.87	2.15	5.36	6.0	75.7	70.85
Jan.	62.35	41.65	76.7	71.27	10.54	11.47	1.105	2.42	5.5	6.0	58.78	65.44
Feb.	29.0	24.5	68.94	59.94	11.6	13.15	1.279	2.71	6.04	7.0	109.36	97.55
Mar.	42.7	23.9	58.7	46.9	14.9	16.8	1.39	3.18	6.78	7.87	190.9	184.27
Apr.	28.24	14.32	49.9	40.1	21.4	23.46	1.53	3.27	7.25	8.2	246.9	243.8
May.	6.3	12.27	35.36	29.0	29.3	30.9	1.41	3.0	8.7	9.35	335.56	349.25
Jun.	0.0	0.46	27.2	21.68	33.8	34.92	1.33	3.88	10.32	11.9	472.63	459.4
Jul.	0.0	0.0	25.9	20.3	36.2	37.2	1.35	3.86	10.2	11.46	556.13	496.93
Aug.	0.0	0.0	26.57	20.95	34.9	36.3	1.26	3.47	10.05	11.5	540.4	463.15
Sep.	0.09	1.93	31.0	25.35	30.8	31.96	1.13	2.95	9.2	10.4	409.42	351.6

Due to the occurrence of Mandali basin between stations Badra climate and Khanaqin, the arithmetic mean is used to extract the monthly values of different climatic elements of the proposed station Mandali Table 2.

Table 2: The monthly averages of rainfall, relative humidity, temperature, wind speed and sun shine and evaporation basin class (a) for the period (1990-2013), calculated for the station Mandali (Ma) proposed.

Months	Rainfall (mm)	R.H.%	Temperature (°C)	Wind Speed (m/sec)	S.Sh.(h./day)	Evaporation (mm)
Oct.	16.65	37.07	25.95	1.77	8.0	254.9
Nov.	50.4	58.65	17.65	1.47	6.87	119.96
Dec.	42.1	69.07	12.3	1.51	5.68	73.27
Jan.	52.0	73.98	11.o	1.76	5.75	62.11
Feb.	26.75	64.44	12.37	2.0	6.52	103.45
Mar.	33.3	52.8	15.85	2.28	7.3	187.6
Apr.	21.28	45.0	22.43	2.4	7.7	245.35
May.	9.3	32.3	30.1	2.2	9.0	342.4
Jun.	0.23	24.44	34.36	2.6	11.11	466.0
Jul.	0.0	23.1	36.7	2.6	10.83	526.53
Aug.	0.0	23.76	35.6	2.36	10.77	501.77
Sep.	1.01	28.17	31.4	2.04	9.8	380.51
Total	253.02					
Monthly Mean		44.4	21.3	2.08	8.27	271.98

Potential evapotranspiration

Thornthwiate suggested an equation to calculate the potential evapotranspiration after conducting several experiments on various semi-wet and semi-arid climate types depending on the temperature only [4] Thornthwiate's equation is applied to calculate the monthly potential evapotranspiration as shown in Table3.

Table 3: Potential evapotranspiration (PE) mm for Mandali Basin by Thornthwiate.

Months	a=2.662 t °C	t/5	$J=(t/5)^{1.514}$	10t/J	$(10t/J)^a$	PE (mm)	DT/360	PE_c (mm)
Oct.	25.95	5.19	12.1	1.919	5.669	90.704	0.68	61.67
Nov.	17.65	3.53	6.75	1.305	2.031	32.496	0.57	18.24
Dec.	12.3	2.46	3.907	0.91	0.778	12.448	0.49	6.1
Jan.	11.0	2.2	3.299	0.813	0.576	9.216	o.5	4.61
Feb.	12.37	2.47	3.931	0.915	0.789	12.624	0.51	6.438
Mar.	15.85	3.17	5.736	1.172	1.525	24.4	0.62	15.128
Apr.	22.43	4.48	9.683	1.659	3.847	61.552	0.64	38.16
May.	30.1	6.02	15.146	2.226	8.416	134.656	0.77	103.68
Jun.	34.36	6.87	18.499	2.542	11.983	191.728	0.92	176.39
Jul.	36.7	7.34	20.448	2.715	14.278	228.448	0.93	212.45
Aug.	35.6	7.12	19.527	2.633	13.159	210.544	0.92	193.7
Sep.	31.4	6.28	16.147	2.323	9.428	150.848	0.82	123.69
Total			135.173			1317.69		960.256

where:

PE: Monthly potential evapotranspiration (mm), PE_C: corrected potential evapotranspiration (mm), D: number of day in the month, T: number of possible sun shine (hours).

Water surplus (WS) and water deficit (WD)

Water surplus is defined as the excess of rainfall over the corrected potential evapotranspiration values during specific months of the year, while water deficit is the excess of corrected potential evapotranspiration values over rainfall during the remaining months of that year. According to [5], the actual evapotranspiration APE can be derived as follows:

$$APE = PEc \quad \text{when } P \geq PEc$$
$$APE = P \quad \text{when } P < PEc$$

In the first case (water surplus period) the value of rainfall is greater than PEc, and the APE is equal to the PEc value; while in the second case (water deficit period) PEc is greater than rainfall; the APE is equal to rainfall values as expressed in the following:

$WS = P – PEc$

$P > PEc$, $PEc = APE$

$WD = PEc – P$

$P < PEc$, $P = APE$

where:

WS: Water surplus (mm)

WD: Water deficit (mm), P: Rainfall (mm), PEc: Corrected potential Evapotranspiration factor (mm).

APE: Actual Potential Evapotranspiration factor (mm).

The WS and WD are calculated without using the soil moisture (equal to zero). Table 4 shows the monthly averages of APE, WS and WD; the water surplus period is limited between November and March because rainfall exceeds PEc, while the remaining months represent water deficit period where PEc exceeds the rainfall.

The WS amount is (153.034 mm) from total rainfall (253.02 mm), therefore the water surplus ratio from the annual rainfall can be represented as:

WS % = WS / P × 100

WS % = 153.034 / 253.02 × 100 = 60.87 %

This percentage represents the groundwater recharge and surface runoff. While the amount of WD is (860.59mm) from the corrected potential Evapotranspiration (PEc), which equal to 39.13% from the total rainfall as in the following equation:

WD % = 100 - WS %

WD % = 100 – 60.87 % = 39.13 %

Fig. 2 shows the relationship between the monthly average of rainfall and corrected potential evapotranspiration, which shows the water surplus and water deficit periods.

Surface Runoff is an important component of the water balance of the hydrological basins. The annual runoff verified account of the water surplus in the study area by adopting the following mathematical formula [6].

$R_s = (P – 17.8) P / 254$

$Ws = R_s + R_e$

Where:

P: Total annual rainfall (mm)

R_s: surface Runoff (mm)

R_e: Groundwater Recharge (mm)

Table 4:Water surplus of the study area for the period (1990-2013).

Months	P(mm)	PE_c(mm)	AE(mm)	WS(mm)	WD(mm)
Oct.	16.65	61.67	16.65	0	45.02
Nov.	50.4	18.24	18.24	32.16	0
Dec.	42.1	6.1	6.1	36.0	0
Jan.	52.0	4.61	4.61	47.39	0
Feb.	26.75	6.438	6.438	20.312	0
Mar.	33.3	15.128	15.128	18.172	0
Apr.	21.28	38.16	21.28	0	16.88
May.	9.3	103.68	9.3	0	93.7
Jun.	0.23	176.39	0.23	0	176.16
Jul.	0.0	212.45	0.0	0	212.45
Aug.	0.0	193.7	0.0	0	193.7
Sep.	1.01	123.69	1.01	0	122.68
Total	253.02	960.306		154.034	860.59

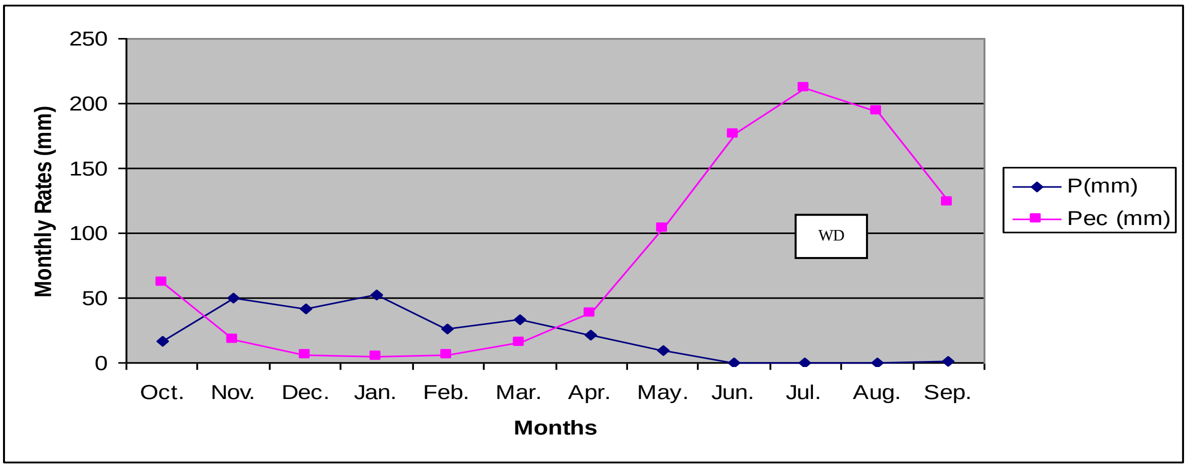

Fig.(2) : The relationship between monthly averages of rainfall (P)and corrected potential evapotranspiration, shows water surplus(WS) and the water deficit (WD)for the study area.

The limitations of the applied this equation to calculate the runoff basins hydrological is that the total annual rainfall is not less than 178 mm.

The water balance calculations is performed by depending on the rainfall and the potential evapotranspiration rates for the period (1990-2013) set out in the Table 4 where the total annual rainfall was 253.02 mm with water surplus (154.034) mm, which is constitute a percentage of annual rainfall (60.87%) mm. This increase is divided into the surface runoff (Rs) value of (7.47) mm, the rate of annual rainfall (2.95%), and the groundwater recharge (Re) value (146.56 mm) and the rate of annual rainfall (57.92%). In general, the rate of water surplus generated from the annual rainfall was 60.87% offset 39.13% water loss through actual evapotranspiration.

Climate classification

The average of the monthly rainfall values and temperature is used to determine the climate detailed basin Mandali according to the type of classification [7, 8] who adopted the Humidity Index (HI), which represents the ratio between the rainfalls (P) to the potential evapotranspiration (PE). According to the application of both classifications, which are mentioned above, the predominant type of climate during the months of the year of the study area as shown in the Table 5.

H.I. = P/PE

Table 5: Evaluation of monthly climate averages in the study area according to the (Brown and Cocheme, 1973)[8] and (Kettanha and Gangophhyaya, 1974)[7].

Month	P (mm)	PE (mm)	H.I.	Kettanha and Gangophhyaya,1974 [8]	Brown and Cocheme, 1973 [7]
Oct.	16.65	90.704	0.183	Moderate to Dry	Dry
Nov.	50.4	32.496	1.55	Humid	Humid
Dec.	42.1	12.448	3.38	Humid	Humid
Jan.	52.0	9.216	5.64	Humid	Humid
Feb.	26.75	12.624	2.12	Humid	Humid
Mar.	33.3	24.4	1.36	Humid	Humid
Apr.	21.28	61.552	0.345	Moist	Moist
May.	9.3	134.656	0.07	Dry	Very Dry
Jun.	0.23	191.728	0	Dry	Very Dry
Jul.	0.0	228.448	0	Dry	Very Dry
Aug.	0.0	210.544	0	Dry	Very Dry
Sep.	1.01	150.848	0	Dry	Very Dry

The climate class is identifying by using the annual dry coefficient, which is suggested by Al-Kubaisi [9]. This classification, which depends on the rainfall and temperature, shows that the climate of the study area is a Sub arid.

Conclusions

1. The different climatic transactions account for the proposedstation Mandali of climate information obtained through the stations of Khanaqin and Badra period (1990-2013).
2. This study showed that there is the water balance in the basin by 60.8% of the amount of rainfall, which is equivalent to 154.034 mm.
3. The water balance is divided into surface runoff 7.47 mm with a rate of 2.95% and groundwater recharge of

146.56 mm with a rate of 57.92% of the annual rainfall. The water deficit represents 860.59 mm of the corrected potential evapotranspiration.

4. This study showed that the climate of the study area is between the wet climates in winter to the dry climate in summer and in general, it can be considered that the climate of the region is Sub arid.

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