Water Availability and water balance in Erbil Governorate

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المستخلص

تمت دراسة عناصر الموازنة المائية في اربعة مناطق مختارة ضمن محافظة اربيـل وهي (سوران ، شقلاوة ، عينكاوة و اربيل).

اخذت المعدلات الشهرية للعناصر المناخية المختلفـــة للمنـــاطق الاربعـــة للفتـــرات (2001 - 2004) بالنسبة لمحطات سوران ، شقلاوة وعينكاوة وذلك حسب توفر البيانات.

اما بالنسبة لمحطة اربيل اخذت العناصر المناخية للفترة (1992 – 2004).

تم ايجاد عناصر الموازنة المائية خلال فترات الفائض المائي والعجز المائي كما تـــم استخدام بعض المؤشرات المناخية لتقييم المناخ في المناطق الاربعـــة المـــشار اليهـــا وهـــي مؤشري سيليانينوف ومؤشر Brown & Cocheme .

Abstract

Water balance parameters were studied in four locations in Erbil Governorate which are Soran , Shaqalawa , Einkawa and Erbil .

The mean monthly climatic parameters were taken for the different locations for the periods (2001 – 2004) to Soran, Shaqlawa , Einkawa according to the availability of data .

For Erbil location, the climatic data was taken for the period (1992 – 2004). Water balance parameters were found during the Water Surplus Periods and water Deficit Periods .

Some climatic Indexes were also found for the four locations. The evaluation of the climate in the four locations was found according to Cilianinov and Brown & Cocheme classifications.

Introduction

Climate is the most important factor effecting the vegetation cover and the soil. It also affects the hydrological parameters such as evaporation, evapotranspiration and runoff [1, 2]

The climatic water balance of any region depends on the input specially rainfall and the out put in the term of evapotranspiration [3 , 4]

Analysis of hydrologic components over a drainage area is the tool used to quantify water availability and for finding solutions to water resources problems.

For a given set of atmospheric conditions , evapotranspiration obviously depends on the availability of water. If sufficient moisture is always available to completely meet the needs of vegetation fully covering the area, the resulting evapotranspiration is called potential evapotranspiration (PE) [5] .

Dry and humid periods are defined as water deficit (WD) and water surplus (WS) respectively .

Water surplus occurs when Rainfall (p) exceeds potential evapotranspiration (PE), while water deficit occurs when PE exceeds P. [6,7].

As shown in table(1) Brown and Cocheme [8] used the Humidity Index (H1) to classify the type of climate and the water availability periods where :

$$H\,1 = \frac{P}{PE}$$

Table (1) : represents this classification

H1	Climate type
H1 > 1	Humid
H1 ≤ 1 < 2	Moist
2H1 ≤ 1 4 < H1	Intermediate
4 H1 ≤ 1 ≤ 10H1	Dry
10 H1 < 1	Very Dry

Cilianinov used the mean monthly temperature and rainfall to determine the type of climate through the following expression [9] :

$$K = 10 \ \Sigma P / \Sigma Tc^{.}$$

Where

74

K = thermal humidity index

ΣP = summation of rainfall (mm) for the period when $Tc \geq 10\ C$

ΣTc = summation of the temperature for the same period .

Cilianinov Index can be used a Climatic Index and Agricultural Index to determine the agricultural climate zones.

Table (2) : shows the type of climate according to Cilianinov Index

K	Type of climate
0.0 – 0.1	Desert climate
0.1 – 0.2	Semi Desert climate
0.2 – 0.3	Mediterranean climate
0.3 – 0.4	Mountainous climate

The values of K more than 0.4 indicate also rainy mountainous climate

Erbil Governorate lies within the Semiensured to the ensured rainy zones. [10]

The plantation of the winter corps specially wheat and barely depends mainly on rainfall during the winter and spring seasons , so the knowledge about the period of water surplus and water deficit and other climatic parameters are very important for the success winter crop cultivation in the region.

Data Analyzed

Four locations were determined in Erbil Governorate which are Soran, Shaqlawa , Einkawa and Erbil , Fig. (1) shows these locations, and table (3) shows the altitude , latitude and longitude of these locations.
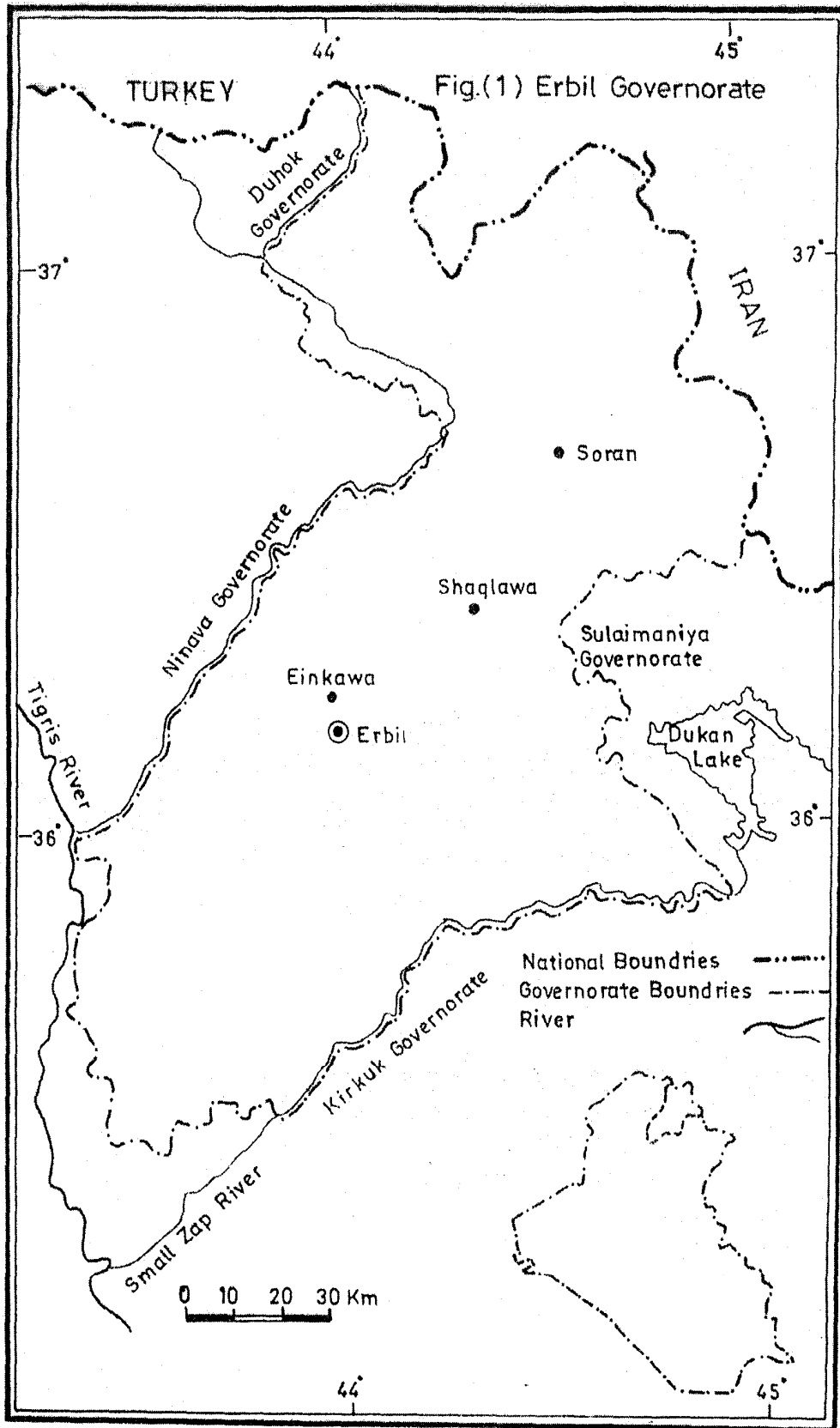
Fig.(1) Erbil Governorate

Table (3) : shows the Altitude, Latitude and longitude of these locations

Stations	Altitude (m)	Latitude (degree)	Longitude (degree)
Soran	680	36. 39	44. 32
Shaqlawa	920	36. 23	44. 20
Einkawa	434	36. 13	44. 01
Erbil	420	36. 11	44. 00

The analysis shows the followings points :

1- The mean monthly climatic elements for Soran , Shaqlawa , Einkawa and Erbil stations were determined in tables (4 , 5 , 6 , 7) .

2- Karuffa equation was used to determine the (PE) , the equation was:

$$PE = 1/3 \ PTc^{1.34}$$

where

P = is the mean daily percentage of annual day time hours which is found from FAO tables [11]

Tc = mean monthly temperature in C .

This equation was used in certain location in Iraq which gives a good accuray [12] .

3- The water balance parameters were found during the water surplus (WS) period and water deficit (WD) period for the four locations.

4- The climate of the four locations was evaluated according to Brown Humidity Index (H1) and Cilianinov Index (K) .

Result and discussion

1- Analysis of water balance parameters

Fig. (2 , 3 , 4 , 5) showed the of water surplus and water deficit periods for Soran , Shaqlawa , Einkawa and Erbil locations .

The value of (PE) indicates a clear rapprochement for Soran and Shaqlawa locations where their mean annual values equal to (1692) and (1697) mm respectively. Einkawa showed a small increase (10 %) in their
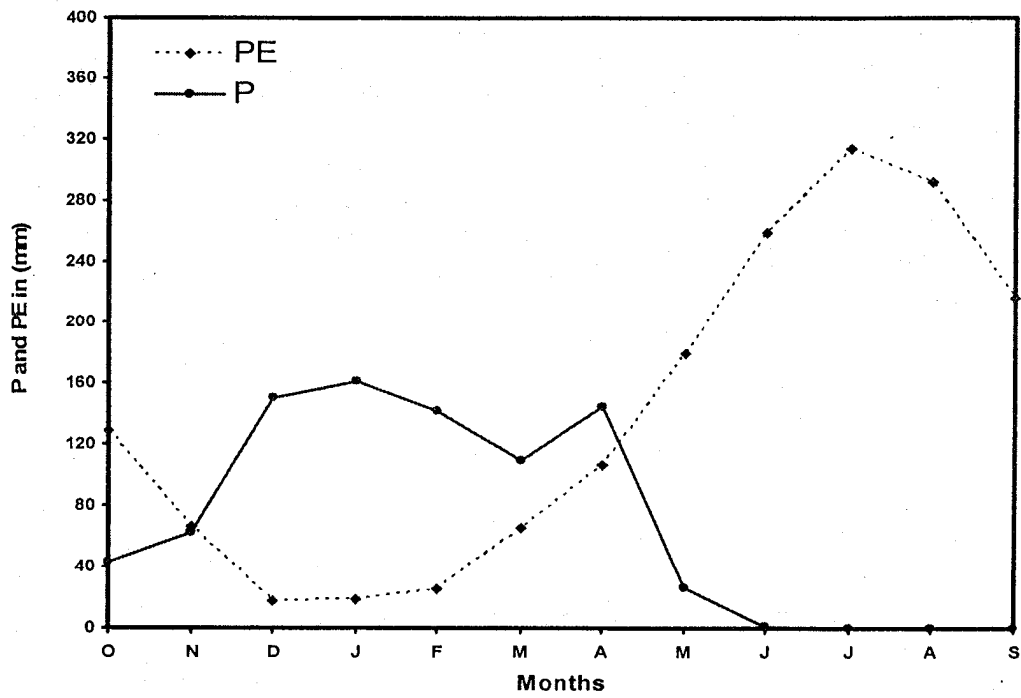
Fig (2) : Water Surplus and Water Deficit (mm) at Soran station
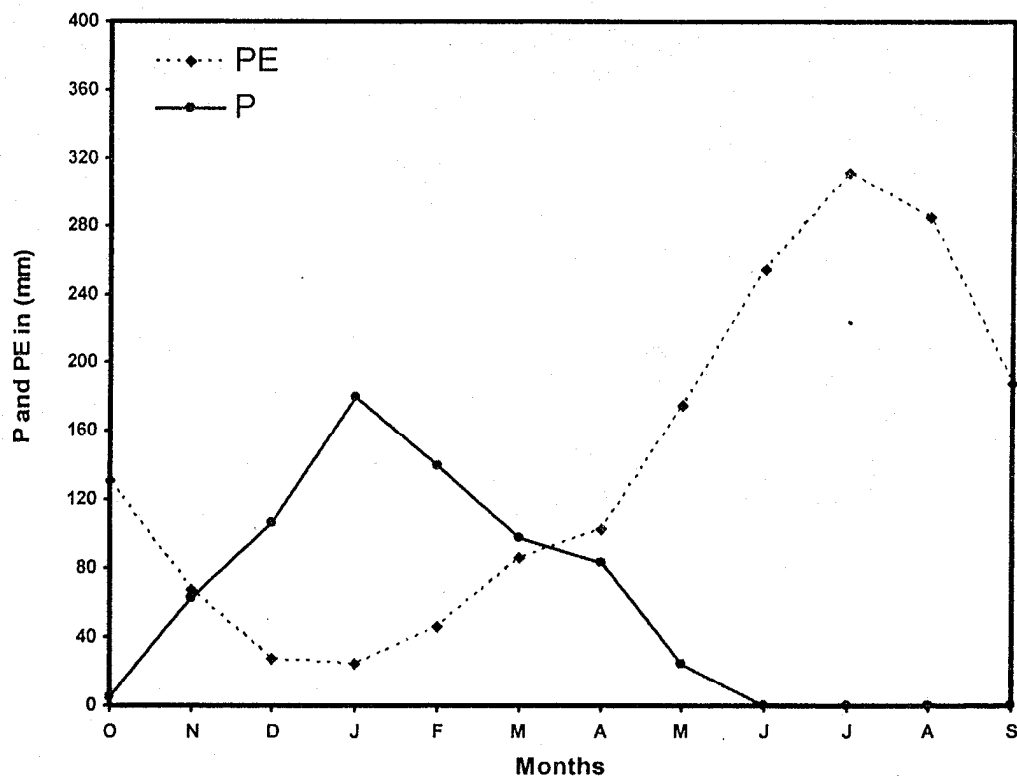

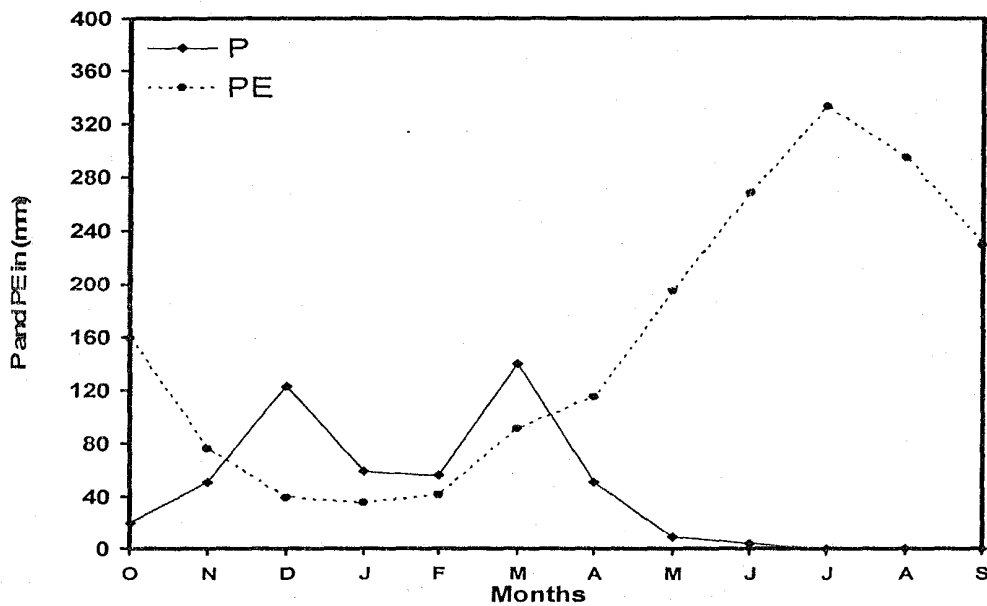**Fig (3) :** Water Surplus and Water Deficit (mm) at Shaqlawa station

Fig (4) : Water Surplus and Water Deficit (mm) at Einkawa station
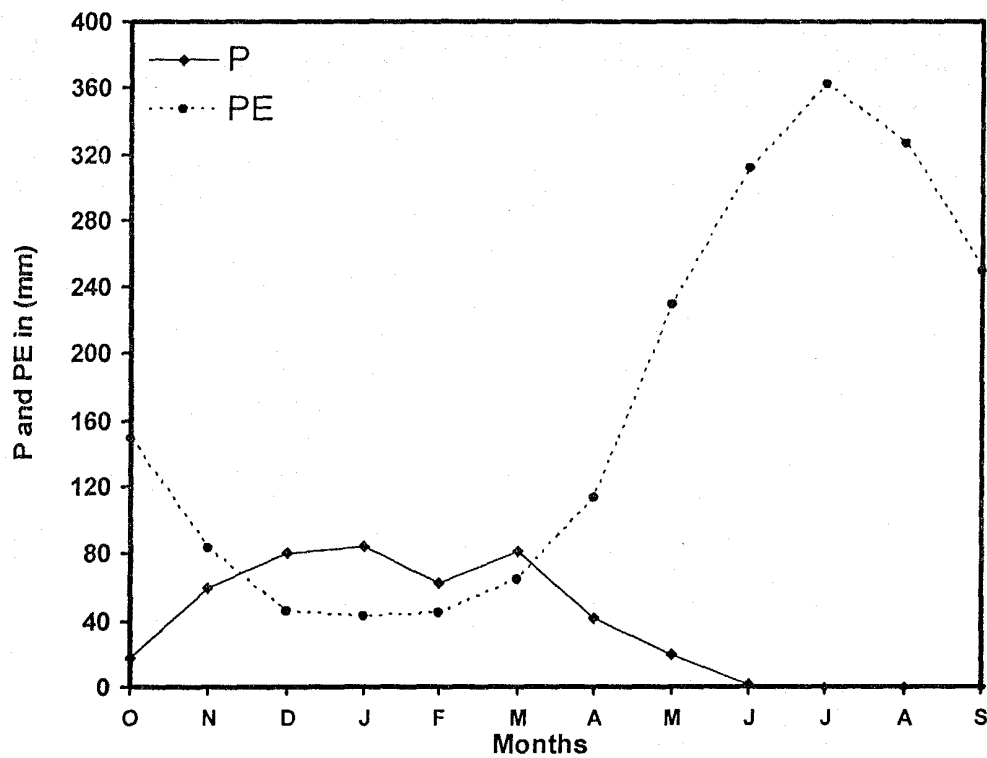

Fig (5) : Water Surplus and Water Deficit (mm) at Erbil station

mean annual value of (PE) compared with that of Soran and Shaqlawa which reachs (1876) mm. Erbil showed a clear increase (20 %) in their mean annual value of (PE) compared with that of Soran & Shaqlawa and its value reaches (2023) mm. The high value of PE in Erbil is due to especially their high monthly temperature compared with those of other locations.

The Rainfall value showed a clear difference between the four locations in Erbil governorate where their mean annual values equal   : 710 , 700 , 513 , 450 mm for Soran Shaqlawa , Einkawa and Erbil respectively.

The Water Surplus (WS) period extended five months (Dec. , Jan. , Feb. , Mar. , Apr.) for Soran while the (WS) in Shaqlawa , Einkawa and Erbil extended four months (Dec., Jan. , Feb. , Mar.) .

The water surplus in Soran , Shaqlawa , Einkawa and Erbil are 517 , 349, 172 and 109 mm respectively.
The water surplus period in Soran , Shaqlawa , Einkawa and Erbil was presented in table (8) .

The ratio (p/ PE) reaches its maximum value in Soran (3.02). But its minimum value is shown in Erbil (1.54) .

In Shaqlawa and Einkawa the ratio (p/PE) is (2.86) and (1.83) respectively. The ratio (WS/P) reaches 0.73 , 0.66 , 0.45 and 0.35 for Soran , Shaqlawa , Einkawa and Erbil respectively.

The water surplus percentage (WSP) reaches to (24%) , (33%) , (49%) and (61 %) for Erbil , Einkawa , Shaqlawa and Soran respectively.

The minimum value of WSP and WS in Erbil is due to high monthly temperature and high monthly (PE) with regard to the other locations. Table (9) shows the water deficit period for the four locations.

Erbil location gives the maximum values of water deficit which reach (1682) mm while its values arrive (1327) , (1339) , (1665) mm for Soran , Shqlawa and Einkawa locations respectively.

Water Deficit period extended seven months in Soran and eight months in Erbil , Einkawa and Shaqlawa. This is due to their (p) & (PE) values.

During this water deficit period the rainfall is mainly reduced and finished in the summer months and September, while the (PE) is dominant of the water balance.

The values of (PE/P) are high in this period for all the locations and they range between (8.6 - 12.8).
The ratio (WD/PE) for all the locations is ranged between (0.88 - 0.99) .

Table (8) : values of (PE) and (P) in mm during the water surplus
period for Soran Shaqlawa , Einkawa and Erbil location

Parameters / Location	P	PE	WS	P / PE	WS / P
Soran	705	233	517	3.02	0.73
Shaaqlawa	525	183	349	2.85	0.66
Einkawa	378	206	172	1.83	0.45
Erbil	308	199	109	1.54	0.35

Table (9) : values of (PE) and (P) in mm during the Water Deficit
period for Soran , Shaqlawa , Einkawa and Erbil location

Parameters / Location	P	PE	WD	PE/P	WD/PE
Soran	132	1459	1327	11	0.90
Shaaqlawa	175	1514	1339	8.6	0.88
Einkawa	135	1670	1665	12.4	0.99
Erbil	142	1824	1682	12.8	0.92

2- Climate Evaluation

A – Cilianinov Classification :

Cilianinov Index (K) was shown in table (10) for Soran,
Shaqlawa, Einkawa and Erbil locations.

From this table we can deduce that all the values of (K) were
ranged between (0.32 – 0.63).

According to Cilianinov climatic classification all the locations
lies within the mountainous climate where their values of K exceed 0.3 .

Table (10) : cilianinov Index for Soran , Erbil , Shaqlawa and Einkawa
locations

Station	Period for which $t \geq 10$ C	ΣP	Σt	K
Soran	All the months of the year except Jan. Feb. Dec.	385	6104	0.63
Shaqlawa	All the months of the year except Jan. Feb. Dec.	272	6117	0.44
Einkawa	All the months of the year except Jan. Feb. Dec .	305	6641	0.45
Erbil	All the months of the year except Jan. Feb. Dec .	224	6830	0.32

81

B- Brown and Cocheme classification :

Tables (11 , 12, , 13, 14) show the relation between type of climate according to Brown and Cocheme classification of the four locations. From this classification one can deduce the followings :

1- The period from Dec. to March in Erbil , Shaqlawa and Einkawa the dominate type of climate is Humid , while in Soran the Humid period is from Dec. to April. The values of (HI) are ranged between (1.13– 8.47)

2- The dominate climate in Nov. in all the regions is Moist where the values of H1 ranged between (0.67 – 0.94)

3- During April the type of climate varies in all the regions, it is Moist in Shaqlawa, intermediate in Einkawa and Erbil and Humid in Soran.

4- In May the dominate type climate is Dry in Soran and Shaqlawa while it is Very Dry in Erbil and Einkawa.

5- The period from June till the beginning of Oct., the type of climate in all the regions is Very Dry , where the value 10 H1 < 1 .

6- In Oct. the type of climate was varied in all the regions where it is Dry in Erbil and Einkawa and intermediate in Soran and Very Dry in Shaqlawa. This is due to their monthly values of rainfall and potential evapotranspiration.

Conclusions

1- The calculated mean annual (PE) classified according to their magnitude as : 2023 , 1876 , 1697 , 1692 mm for Erbil , Enkawa , Shaqlawa and Soran respectively.
The difference in (PE) is due to the variations in air temperature .

2- Rainfall shows a clear difference between these locations where the mean annual Rainfall is (837 , 700 , 512 , 450) mm for Soran , Shaqlawa, Einkawa and Erbil respectively.
The difference in elevation of these locations affects mainly their rainfall.

3- Water Surplus period extended four months (Dec. , Jan., Feb., Mar.) in Erbil , Shaqlawa , Einkawa while in Soran it extended five months (Dec., Jan. , Feb., Mar. Apr.) .

4- Erbil location gives a maximum value of Water Deficit where it reaches (1681) mm / year while it reaches (1335 , 1339 , 1535) mm/ycar for Soran , Shaqlawa and EinKawa respectively.

5- The type of climate according to Cilianinov classification is mountainous climate in all the locations.

6- Brown and Cocheme classification shows two mainly periods, the first extends from Dec. to April where the type of climate is Humid in all the locations.

The second period is from (Jun. to Oct.) where the type of climate is very Dry. This is due to their values of (P) and (PE).

In the other months the type of climate varies from one location to other.

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Table (4) : the monthly mean meteorological elements at Soran station for the period (2001 –2004)

Months / Meteo. Element	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Mean air temp.(C)	4.9	5.7	11	15.2	21.5	28	33.5	32	27.3	19.5	12.5	5
R.H. %	78	78	66	69	58	46	43	40	46	57	65	77
Rainfall (mm)	161	141	109	144	26	1	0	0	0	43	62	150
(n) hrs.	3.9	3.6	5.6	5.8	9.8	12.1	12	11.7	10.3	6.5	6	3.2
(N) hrs.	9.8	10.6	11.8	12.9	13.9	14.3	14.1	13.4	12.3	11.1	10.1	9.55
n/N	0.4	0.34	0.47	0.45	0.7	0.85	0.85	0.87	0.84	0.58	0.59	0.34
Evaporation (mm)	13.9	20	72.85	96	180	264	294	283	216	100	48	15

Table (5) : the monthly mean meteorological elements at Erbil station for the period (1992 –2004)

Months / Meteo. Element	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Mean air temp.(C)	9.1	9.7	11.1	16	26	32	36	35	30	22	15	10
R.H. %	67	63	59	53	38	26	25	25	28	37	53	66
Rainfall (mm)	84	63	81	42	20	2	0	0	0	18	60	80
Wind speed m/s	2.3	3.1	3	2.9	3.1	2.9	2.8	2.2	2.4	2.3	2.1	2
(n) hrs.	4.8	5.9	6.6	7.1	9.1	11.4	11.2	11.2	10.1	7.9	6.1	4.5
(N) hrs.	9.8	10.7	11.8	12.9	13.9	14.2	14.1	13.7	12.2	11.1	10.1	9.5
n/N	0.49	0.56	0.56	0.55	0.65	0.80	0.80	0.81	0.82	0.71	0.60	0.47
Evaporation (mm)	45	63	110	151	262	326	409	389	296	189	90	47

Table (6) : the monthly mean meteorological elements at Shaqlawa station for the period (2001–2004)

Meteo. Element \ Months	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Mean air temp.(C˙)	5.5	7.3	12.7	14.9	21.2	28.2	32.1	31.6	24.9	21.4	12.7	6.4
R.H. %	74	72	68	68	64	45	36	35	36	43	56	61
Rainfall (mm)	180	140	98	83	24	0	0	0	5	63	107	61
Wind speed m/s	2.5	3.3	3.0	3.7	2.9	2.9	2.4	2.0	1.3	1.7	2.5	1.1
(n) hrs.	5.3	5.7	7.7	10.3	11.1	12	11.3	10.9	10	7.2	3.3	4.1
(N) hrs.	9.8	10.7	11.8	12.9	13.9	14.2	14.1	13.3	12.2	11.1	10.1	9.5
n/N	0.54	0.53	0.65	0.79	0.80	0.84	0.80	0.81	0.81	0.65	0.33	0.43
Evaporation (mm)	31	42	93	108	232	345	384	344	264	217	51	18

Table (7) : the monthly mean meteorological elements at Einkawa station for the period (2001–2004)

Meteo. Element \ Months	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Mean air temp.(C˙)	7.9	9	14.3	17.1	23	29.4	33.8	32.7	28.9	23.3	14.4	8.5
R.H. %	74	68	63.9	63	43	30	32	32	35	37	54	77
Rainfall (mm)	59	56	140	51	9	3.4	0	0	0	20	51	123
Wind speed m/s	1.5	2.1	1.3	3.5	4.6	3.7	3.4	3.4	3.4	1.5	2.1	1.2
(n) hrs.	5	6.1	7	7.5	10.7	12.8	12	11.5	5	4.3	2.8	2
(N) hrs.	9.8	10.7	11.8	12.9	13.9	14.2	14.1	13.3	12.2	11.1	10.1	9.5
n/N	0.51	0.57	0.59	0.58	0.77	0.90	0.85	0.86	0.41	0.39	0.28	0.21
Evaporation (mm)	46	70	130	138	294	411	440	403	285	240	90	38

Table (11) : Climate according to Brown and Cocheme index at Soran
location

Month	P mm	PE mm	HI	Climate type
Jan.	161	19	8.47	Humid
Feb.	142	25	5.68	Humid
Mar.	109	65	1.67	Humid
Apr.	144	106	1.35	Humid
May	26	180	0.14	Dry
Jun.	1	260	0.003	Very dry
Jul.	0	314	0	Very dry
Aug.	0	293	0	Very dry
Sept.	0	217	0	Very dry
Oct.	43	129	0.33	Intermediate
Nov.	52	66	0.80	Moist
Dec.	150	18	8.3	Humid

Table (12) : Climate according to Brown and Cocheme index at Erbil
location

Month	P mm	PE mm	HI	Climate type
Jan.	84	43	1.95	Humid
Feb.	63	45	1.40	Humid
Mar.	81	65	1.24	Humid
Apr.	42	113	0.37	Intermediate
May	20	229	0.08	Very dry
Jun.	2	312	0.006	Very dry
Jul.	0	362	0	Very dry
Aug.	0	327	0	Very dry
Sept.	0	249	0	Very dry
Oct.	18	149	0.12	Dry
Nov.	60	83	0.72	Moist
Dec.	80	46	1.73	Humid

Table (13) : Climate according to Brown and Cocheme index at Shaqlawa location

Month	P mm	PE mm	HI	Climate type
Jan.	180	24	7.50	Humid
Feb.	140	46	3.04	Humid
Mar.	98	86	1.13	Humid
Apr.	83	103	0.80	Moist
May	24	175	0.13	Dry
Jun.	0	254	0	Very dry
Jul.	0	311	0	Very dry
Aug.	0	285	0	Very dry
Sept.	0	188	0	Very dry
Oct.	5	131	0.03	Very dry
Nov.	63	67	0.94	Moist
Dec.	107	27	3.91	Humid

Table (14) : Climate according to Brown and Cocheme index at Einkawa location

Month	P mm	PE mm	HI	Climate type
Jan.	59	35	1.68	Humid
Feb.	56	41	1.36	Humid
Mar.	140	91	1.53	Humid
Apr.	51	115	0.44	Intermediate
May	9	195	0.04	Very dry
Jun.	3.4	268	0.01	Very dry
Jul.	0	333	0	Very dry
Aug.	0	295	0	Very dry
Sept.	0	229	0	Very dry
Oct.	20	159	0.12	Dry
Nov.	51	76	0.67	Moist
Dec.	123	39	3.15	Humid