ISSN: 0067-2904

# Computation of Climatic Water Balance for Greater Musaiyab Project Site in Babylon Governorate- Central of Iraq

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**Abstract**

The meteorological data recorded in Al-Hilla station for the period (1984-2014) were used to describe the climatic condition of the Greater Musaiyab Project lies in Babylon Governorate, 90Km southern of Baghdad City, central of Iraq. This study found that the summation of rainfall is (112.323 mm), average of relative humidity (47.44%), temperature (25.55 C°), sunshine (8.748 h/day) and the total of evaporation is (2268.463 mm). In this research, three classifications were applied to find the type of climate in the study area. The results of the climate classification show that, the climate of study area is characterized by dry and relatively hot in summer, and cold with low rain in winter. Thornthwiat equation was used to determine the values of the potential evapotranspiration. This study shows that, there is water surplus of (39.12 %) of the total rainfall amount which is equivalent to (112.323 mm).

**Keywords:** Water balance, Potential evapotranspiration, water surplus, climatic condition.

# حساب الموازنة المائية المناخية لموقع مشروع المسيب الكبير في محافظة بابل – وسط العراق

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**الخلاصة**

تم استخدام بيانات الارصاد الجوية المسجلة في محطة مدينة الحلة للفترة (1984–2014) لتقييم الظروف المناخية لمشروع المسيب الكبير الواقع في محافظة بابل 90,كم جنوب محافظة بغداد وسط العراق . حيث بينت الدراسة إن مجموع الساقط المطري يبلغ(112.323 mm) ، معدل الرطوبة النسبية (47.44%)، ودرجة الحرارة(25.55C°)، والسطوع الشمسي (8.748 h/day) اما مجموع التبخرمن سطوح حرة بلغ (2268.463 mm) .تم تطبيق ثلاثة انواع من التصانيف لايجاد نوع المناخ في منطقة الدراسة, وقد اختيرت لملائمتها لمناخ منطقة الدراسة وقد بينت نتائج تحاليل هذه المعطيات ان مناخ منطقة الدراسة يمتاز بأنه حار جاف صيفا ,بارد قليل الامطار شتاءا .كما تم تطبيق معادلة ثورنثويت لايجاد قيم التبخر–نتح الكامن .أظهرت الدراسة وجود زيادة مائية بنسبة (39.12%) من كمية الساقط المطري الكلي الذي يعادل .(112.323 ).

## Introduction:

Greater Musaiyab Project is located in the central part of Iraq, about 90 Km southern of Baghdad Governorate, Central of Iraq, and is situated on the left bank of Euphrates River in Babil Governorate. The Greater Mussaiyab Project area extends between the Euphrates River in the west up to the Main Outfall Drain on the east and north. Between latitudes (32 18′- 32′ 30) north and latitude (44 11′- 44 36′) east. The project area covers approximately (344.780) dunam, (862.000 km$^2$), It's bounded to the north by the north main Drain and to the south by the south main drain, from the east by Wasit

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governorate, and Babylon governorate from the south, as shown in Figure-1. The major physiographic units are composed of 44.8% of silted basins with clay to fine loamy texture, 28.3% embankments with fine loamy to sandy texture, and 11.7% of leveled dunes with coarse loamy to sandy texture, the classification of the Land Capability for Irrigation of the project area has been estimated at nearly 88% of the area would be suitable for irrigation after reclamation, and only 10.4 % of the land was unsuitable or excluded [1]. Irrigation water is brought to the project through Al- Musaiyab Canal, this canal takes its water from the Euphrates River at Al- Hindiyah Barrage, the sediments of the Mesopotamian plain cover the central portion of a synclinal depression [2].

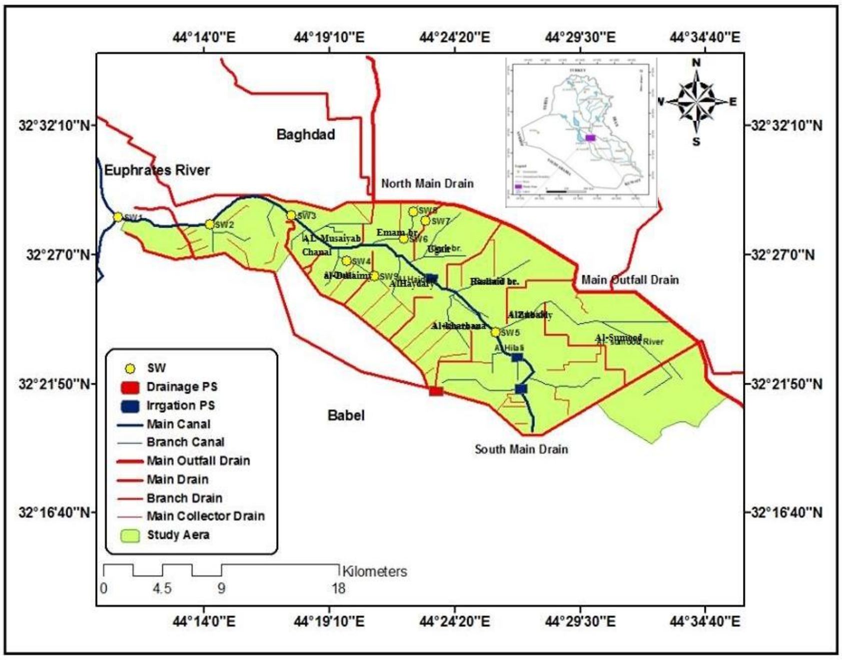


**Figure 1-** Location of study area

This study is aimed to analyze the climate parameters for the available data to calculate the water balance.

**Method and materials**

The climatic data for the study area was taken for the period (1984-2014) of Al-Hilla meteorological station from the Iraqi Meteorological Organization [3], in order to determine the monthly mean values of climatic parameters, as shown in Table-1 and Figure-2. Thornthwiat equation was used to determine the values of the potential evapotranspiration.

The water balance of the study area calculated by using Lerner method, water surplus ratio from the yearly rainfall (Where the soil moisture considered =0) calculated as following [4]:

WS % = WS/P ×100, While: WD% = 100 – WS%

Three of the climate classifications were depended to define the type of climate because there are more suitable to the climate of study area, arid to semi arid areas. The first classification is for Kettaneh, M.S., and Gangopadhyaya, M. 1974 [5], this classification depended on humidity index (H.I) which represents the ratio between the rainfalls to correct potential Evapotranspiration, Table-6.

H.I. = P/PEc, Where:

H.I: Humidity index.

P: rainfall (mm).

PEc: Corrected potential evapotranspiration (mm).

The second classification used in this research is for Brown, L. H. and Cocheme, J., 1973 [6], it used to fined the climate index, according to this classification the climate had been classified in to three classes, based on the relationship between evapotranspiration and rainfall. Climate Index is given by following equation:

C.I. = [(P/PE)-1] /100, Where:

C.I. = Climate index. , P = Rainfall.

PE = Potential evapotranspiration.

When the value of (C.I.) is negative it represent dry climate, whereas positive value of (C.I.) represents a humid climate.

The last classification depended in this research is for Al-Kubaisi, 2004 [7], it used for determining the climate type by using the annual dryness treatment depending on the amount of rainfall and temperature, according to the following equations:

$AI - 1 = (1.0 \times P) / (11.525 \times t)$ …………..(t not equal zero)

$AI - 2 = 2\sqrt{P} / t$

Where:

AI: Aridity index.

P: Annual rainfall (mm).

t: Temperature (C°).

The value of (AI-1) represents the classification of the dominated climate, while the value of (AI-2) represents a modification of the latter classification.

**Results and Discussion:**

The monthly average values of climate parameters in the study area for the period (1984-2014), are determined as following: the total rainfall (112.323mm), the average of relative humidity (47.44%), the average of temperature (23.72°c),wind speed average (m/sec),sun shine duration average (8.748h/day), and the total of the evaporation (2268.448mm),the results listed in Table-1.

**Table 1-** Monthly averages records of climatic parameters in Al-Hilla station for the period (1984-2014) [3].

| Months | Rainfall (mm) | Relative Humidity (%) | Temperatures (C°) | Wind speed (m/sec) | Sunshine (h/day) | Evaporation (mm) |
|---|---|---|---|---|---|---|
| **Oct.** | 3.49 | 46.191 | 25.72 | 1.305 | 8.45 | 163.52 |
| **Nov.** | 28.52 | 62.13 | 18.02 | 1.210 | 7.045 | 81.40 |
| **Dec.** | 19.10 | 66.55 | 11.9 | 1.406 | 6.280 | 57.751 |
| **Jan.** | 23.97 | 71.447 | 11.17 | 1.486 | 6.17 | 53.542 |
| **Feb.** | 11.87 | 64.080 | 13.72 | 1.805 | 7.31 | 80.665 |
| **Mar.** | 11.60 | 52.536 | 18.08 | 2.157 | 7.66 | 140.38 |
| **Apr.** | 10.29 | 43.818 | 23.74 | 2.026 | 8.462 | 189.78 |
| **May** | 3.2 | 35.391 | 27.91 | 1.947 | 9.075 | 264.21 |
| **June** | 0.008 | 29.621 | 32.98 | 2.531 | 11.18 | 333.83 |
| **July** | 0.000 | 29.4 | 35.36 | 2.65 | 11.773 | 353.80 |
| **Aug.** | 0.000 | 31.86 | 34.69 | 1.943 | 11.425 | 306.25 |
| **Sep.** | 0.213 | 36.269 | 31.39 | 1.485 | 10.15 | 243.32 |
| **Average** | | 47.44 | 23.72 | 1.82 | 8.748 | |
| **Total** | 112.323 | | | | | 2268.448 |

There are varies relationships between the climatic variables. Where, Relative humidity is correlated inversely with temperature, evaporation and wind speed; and normally with rainfall as shown in Figure-2.

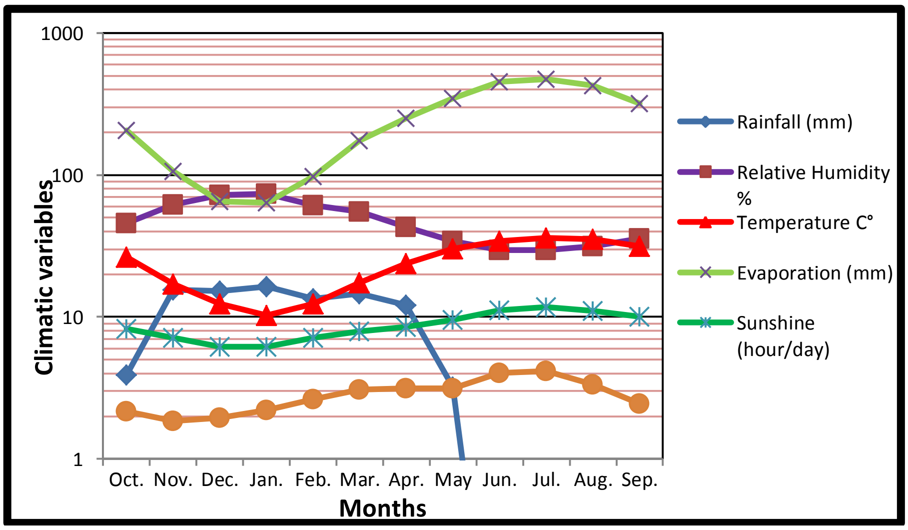


**Figure 2-** Relationships between the climatic variables in Hilla meteorological station for the period (1984-2014).

**Evapotranspiration:**

The potential evapotranspiration is a combine term of evaporation and transpiration, defines as the total loss of water through evaporation and transpiration from the soil plant system. 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 [8-9]. The evapotranspiration in study area is calculated for each month as the follows:

$$\mathbf{PEx = 16\,[10tn / J]^{a}} \quad (1)$$

$$\mathbf{J} = \sum_{j=1}^{12} j \quad \textbf{for the 12 month} \quad (2)$$

$$\mathbf{j = [tn / 5]^{1.514}} \quad (3)$$

$$\mathbf{a = (675 \times 10^{-9})\, J^{3} - (771 \times 10^{-7})\, J^{2} + (179 \times 10^{-4})\, J + 0.492}$$

$$\therefore \mathbf{a = 0.016\, J + 0.5}$$

The value of (a) equals (2.58).

Where:

PEx = Potential evapotranspiration for each month (mm / month).

t = Monthly mean air temperature (C°).

n = Number of monthly measurement.

J = Annual heat index (C°).

j = Monthly temperature parameter (C°).

a = Constant.

The values of potential evapotranspiration for each month are determined in Table-2. The correlation graph of each of the potential evapotranspiration PE, and correct evapotranspiration PEc explained in Figure-3.

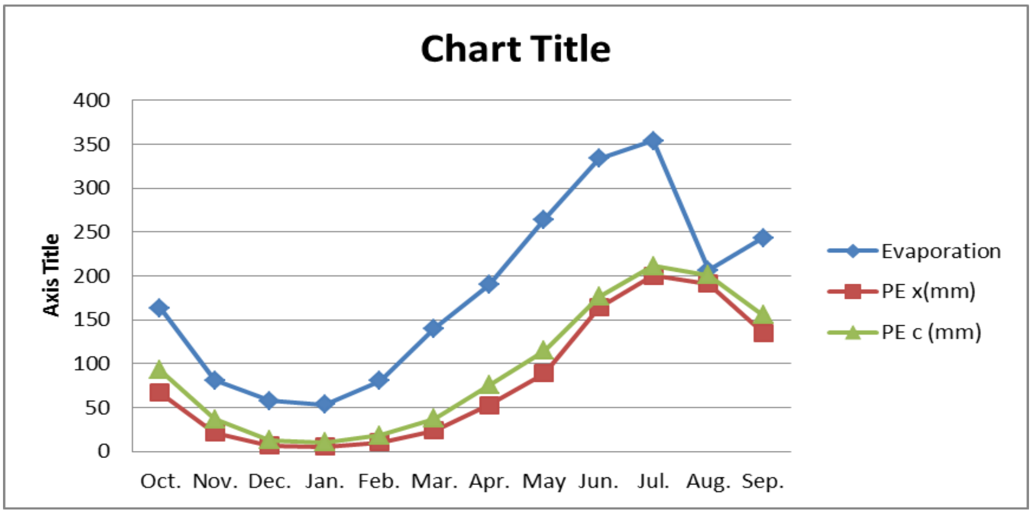


**Figure 3-** Evaporation, PEx and PEc correlation graph in Hilla meteorological ststion for period (1984-2014).

**Table 2-** Potential evapotranspiration (PE) mm for Al-Hilla by Thornthwiate method **(**1948) [8]

| Months | t (C°) | $j=(tn/5)^{1.514}$ | DT/360 | PEx (mm) | PEc (mm) | Epan (mm) |
|---|---|---|---|---|---|---|
| **Oct.** | 26.71 | 11.93 | 0.72 | 92.85 | 66.85 | 163.52 |
| **Nov.** | 18.35 | 6.9 | 0.58 | 37.07 | 21.500 | 81.40 |
| **Dec.** | 13.14 | 3.7 | 0.54 | 12.71 | 6.86 | 57.75 |
| **Jan.** | 11.67 | 3.37 | 0.53 | 10.79 | 5.71 | 53.54 |
| **Feb.** | 14.17 | 3.92 | 0.56 | 18.35 | 10.27 | 80.66 |
| **Mar.** | 19.30 | 4.6 | 0.65 | 37.39 | 24.30 | 140.38 |
| **Apr.** | 24.81 | 10.57 | 0.7 | 75.5 | 52.85 | 189.78 |
| **May** | 31.60 | 13.50 | 0.78 | 114.64 | 89.41 | 264.21 |
| **Jun.** | 36.02 | 17.39 | 0.93 | 176.34 | 163.99 | 333.83 |
| **Jul.** | 38.14 | 19.32 | 0.95 | 211.07 | 200.51 | 353.80 |
| **Aug.** | 37.53 | 18.77 | 0.95 | 200.9 | 190.85 | 306.25 |
| **Sep.** | 32.72 | 16.13 | 0.87 | 155.24 | 135.05 | 243.32 |
| **Total** | | J= 130.1 | DT/360 | 1142.85 | 968.155 | 2268.448 |

**Water Surplus (WS) and Water Deficit (WD):**

Water surplus is define as the excess of rainfall values over the corrected evapotransipiration values during specific months of the year, while water deficit is the excess of corrected evapotransipiration values over rainfall values during the remaining months of that year. The actual potential evapotranspiration (APE) could be derived as follows [9]:

**WS = P – PEc** **(1)**

**PEc = APE, when P > PEc** **(2)**

**WD = PEc – P** **(3)**

**P = APE, when P < PEc** **(4)**

Where:

WS: Water surplus (mm).

WD: Water deficit (mm).

APE: Actual Evapotranspiration (mm).

PEc: Correct potential evapotranspiration.

P : Rainfall

In the first case (water surplus period), If the soil moisture conceded (equal to zero), the water surplus and water deficit are calculated without using it. Monthly averages of APE, WS and WD, all are shown in Table-3. The water surplus amount is (39.12 mm) from annual average rainfall (112.323 mm) and it is restricted between November and March because rainfall amounts exceeds PEc, hence; values of rainfall is greater than correct evapotranspiration, therefore the actual evapotranspiration (APE) equals the correct evapotranspiration. The water surplus represents the surface runoff plus the groundwater recharge after the soil is fully saturated. The soil moisture is consumed either by evaporation from the soil or by plant. Therefore it is considered as a part of the water losses as that of potential evapotranspiration [10].

In the second case (water deficit period) water deficit percentage equals (65.18 %) from annual average rainfall, correct evapotranspiration is greater than rainfall; where the actual evapotranspiration is equal the rainfall. The monthly averages of APE, WS and WD are shown in Table-3.

**Table 3-** The values of water surplus and water deficit for the study area in mm.

| Month | P(mm) | $PE_c$(mm) | APE(mm) | WS(mm) | WD(mm) |
|---|---|---|---|---|---|
| **Oct.** | 3.49 | 66.85 | 3.49 | 0 | 63.36 |
| **Nov.** | 28.52 | 21.500 | 21.500 | 7.02 | 0 |
| **Dec.** | 19.10 | 6.86 | 6.86 | 12.24 | 0 |
| **Jan.** | 23.97 | 5.71 | 5.71 | 18.26 | 0 |
| **Feb.** | 11.87 | 10.27 | 10.27 | 1.6 | 0 |
| **Mar.** | 11.60 | 24.30 | 11.60 | 0 | 12.7 |
| **Apr.** | 10.24 | 52.85 | 10.24 | 0 | 42.61 |
| **May** | 3.2 | 89.41 | 3.2 | 0 | 86.21 |
| **Jun.** | 0.008 | 163.99 | 0.008 | 0 | 163.982 |
| **Jul.** | 0 | 200.51 | 0 | 0 | 200.51 |
| **Aug.** | 0 | 190.85 | 0 | 0 | 190.85 |
| **Sep.** | 0.2 | 126.1 | 0 | 0 | 126.07 |
| **Total** | 112.198 | 959.2 | | 39.12 | 886.292 |

The total annual value of water surplus is (39.12 mm) from total rainfall and it is restricted between November and February because rainfall exceeds PEc. (Where the soil moisture considered =0), the water surplus ratio from the yearly rainfall can be represented as following:

WS % = WS/P ×100

WS% = 39.12 /112.323×100

= 34.82%

WD% = 100 – WS%

WD% = 100 – 34.82 %

= 65.18 %

Figure-4 shows the relationship between the monthly means of rainfall and corrected evapotranspiration, which shows the water surplus and water deficit periods.

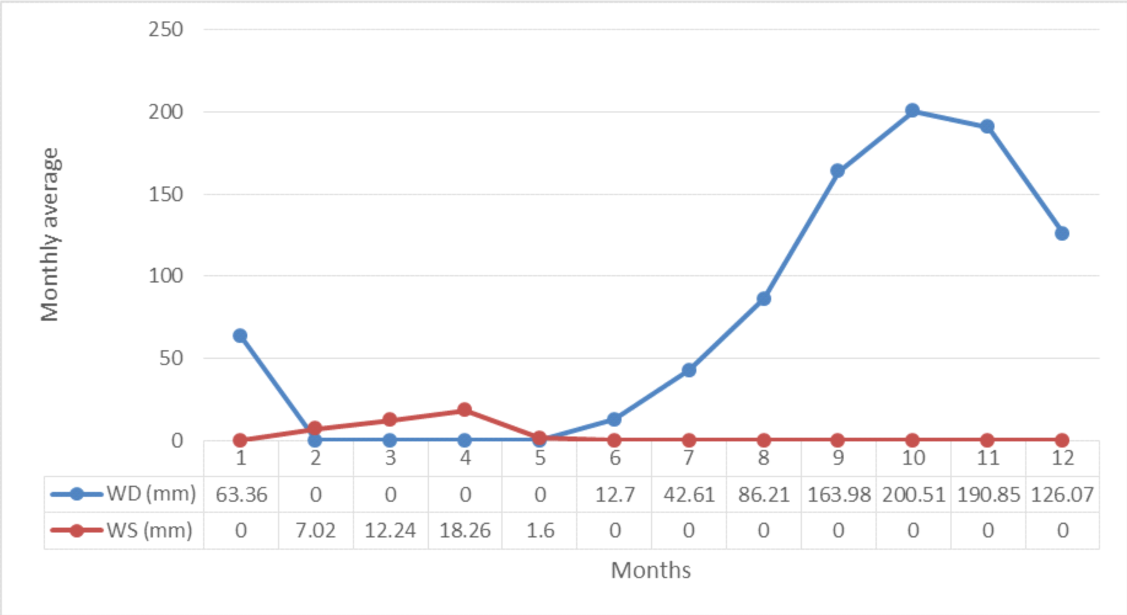


**Figure 4-** The relationship between water surplus (WS) and the water deficit (WD) for the study area.

**Classification of Climate:**

Different classifications for climate proposed by many scientists and researchers to find the variation of the climate elements on which they depend, and there is difficulty together them in one classification [11]. In this work, three of these classifications applied to find the type of climate in the study area as following:

[4] Suggested a classification depended on humidity index (H.I) which represents the ratio between the rainfalls to correct potential Evapotranspiration, the evaluation of monthly climate averages in the study area shown in the Table-4.

**Table 4-** Evaluation of monthly climate averages in the study area after [4].

| Months | P (mm) | PEc (mm) | H.I | Kettaneh and Gangopadhyaya,1974 |
|---|---|---|---|---|
| Oct. | 3.49 | 66.85 | 0.052 | Very dry |
| Nov. | 28.52 | 21.500 | 1.326 | Humid |
| Des. | 19.10 | 6.86 | 2.784 | Humid |
| Jan. | 23.97 | 5.71 | 5.774 | Humid |
| Feb. | 11.87 | 10.27 | 1.155 | Humid |
| Mar. | 11.60 | 24.30 | 0.477 | Humid |
| Apr. | 10.24 | 52.85 | 0.193 | Moderate to Dry |
| May | 3.2 | 89.41 | 0.035 | Moderate to Dry |
| Jun. | 0.008 | 163.99 | 0.000048 | Very Dry |
| July. | 0 | 200.51 | 0 | Very Dry |
| Aug. | 0 | 190.85 | 0 | Very Dry |
| Sep. | 0.2 | 126.1 | 0.00158 | Very Dry |

The second classification depended in this work suggested by [5] for determining the climate type by using the climate index depending on the amount of rainfall and temperature. According to this classification, the climate index (CI) = - 90.16, and the climate type is arid in the studied area as shown in Table-5.

**Table 5-** Classification of the climate according to [5].

| **Claimant Type** | **Range of CI** | **CI in studied area** |
|---|---|---|
| Dry-sub humid | 0.0 to -33.3 | -90.16 |
| Semi-Arid | -33.3 to -66.7 | |
| Arid | -66.7 to -100 | |

Finally, the classification of [6] used to determined the classification of the climate of the study area, this classification depend on the annual dryness treatment depending on the amount of rainfall and temperature, according to this relationship the value of (AI-1) that represents the classification of the dominated climate, and the value of (AI-2) that represents a modification of the latter classification, Table-6, the values becomes as follows:

AI – 1 = 0.38, when comparing this value with the climate type in Table-6, it appears that the dominated climate in the study area is sub arid to arid.

AI- 2 = 0.82, when comparing this value with the values in Table-6, the type of the dominated climate in the study area according to this formula is arid.

**Table 8-** Climate classification depending on values of annual dryness treatment (A-I.1 and A-I.2) after [6].

| Type.1 | Evaluation | Type.2 | Evaluation |
|---|---|---|---|
| AI-1>1.0 | Humid to moist | AI-2>4.5 | Humid |
| | | 2.5 <AI-2< 4.0 | Humid to moist |
| | | 1.85<AI-2<2.5 | Moist |
| | | 1.5<AI-2<1.85 | Moist to sub arid |
| AI-1<1.0 | Sub arid to arid | 1.0 ≤ AI-2<1.5 | Sub arid |
| | | AI-2<1.0 | Arid |

**Conclusions:**

1. This study presented that the water surplus restricted in the months November, December, January and February of (34.82%) of the total rainfall (112.323 mm), while the percentage of water deficit represents (65.18%).
2. The climate of the study area is diversity between the wet climates in winter to the dry climate in summer and in most cases, it can be considered that the climate of the study area is arid to sub arid.

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