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Temporal and Spatial Analysis of Rainfall and Evapotranspiration in Erbil Plain and the Peripheral Areas

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Abstract

Since analysis of spatial events is region specific and cannot be generalized, local studies are of vital importance to identify the most accurate interpolation methods. Furthermore, the trend analysis of climatic parameters at different time scales is helpful for making a better climate change adaptation and mitigation plan to overcome water scarcity. Accordingly, the current study was proposed to detect trends in rainfall and evapotranspiration at monthly and annual time scales over the Erbil plain and the surrounding area using parametric and non-parametric tests. Moreover, four deterministic and five geostatistical methods were evaluated for searching the best interpolation method to generate a continuous surface for the indicated climatic variables. The results revealed that the majority of data sets are categorized useful class and serially independent. Furthermore, it was found both rainfall and potential evapotranspiration have a mix of upward and downward trends and most of them are insignificant at 5% level of significance. Further, the interpolation analysis indicated that local polynomial interpolation (LPI) method was proven to be best interpolator for generating continuous surfaces for rainfall and ETo over the area under study followed by the empirical Bayesian Kriging method.

Keywords: Climatic variables; Trend analysis; interpolation methods; Erbil plain; TOPSIS

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Introduction

As the average global surface temperatures have increased notably worldwide in the latest decades, changes in other components of the hydrological cycle might also be anticipated [1]. Rainfall and evapotranspiration are the two largest components of the water budget in fields like hydrology and hydrometeorology. Thus, it is crucial to appraise changes in these two components in terms of long-term trends, and/or multi decada variability for an insight on the variation in the water budget of a given region. [2].

Severe change in climatic variables like rainfall and evaporation are affecting the flow regimes substantially [3]. Obada, Alamou [4] reported that analyses of the spatial and temporal changes in rainfall and evapotranspiration provide a clear understanding of the impact of anthropogenic factors on the hydrological processes of basins. Chaouche, Neppel[5] have noticed an increase in annual mean temperature and annual potential evapotranspiration throughout 13 catchments in the western part of the French Mediterranean area, whereas annual rainfall did not show any obvious trend.

Seasonal and spatial variabilities of rainfall have a profound impact on spatio-temporal variation runoff, soil moisture and groundwater and consequently affects the frequency of flood and drought, and hence cropping productivity [6]. On the other hand, Shadmani, Marofi [7] revealed that evapotranspiration is the most important variable for identifying the climate change. Khanmohammadi, Rezaie [8] highlighted that increasing and decreasing trends of potential evapotranspiration were assigned to an increase in air temperature and a decrease in wind speed, respectively.

The available tests for detecting trends of hydro-climatologic time series can be categorized into parametric and non-parametric techniques [9]. The only assumption of non-parametric test is the independency of the data. It is insensitive to type of data distribution and will not be affected presence of outliers [10]. Numerous parametric and non-parametric methods were used to detect changes in time series in different fields since 1970. Some of these techniques are Sen's slope, linear regression, Spearman rank test and Mann–Kendall test [3].

Making climatological data available for a given country is an essential task and to cover an area or the whole country with these data, gathered data from meteorological stations need to be interpolated [11].

The technique of polynomial functions can fit functions through the observations using order polynomials of x-order. This technique is characterized by being accurate for interpolating climatic data of monthly and yearly scales, but is less accurate for higher resolutions such as hours and days [11].

Insufficient information on climate variable like rainfall can cause large costs to different sectors, such as agriculture, infrastructures, etc. It is commendable to mention that rain gauge network in study area presents only point estimates for climatic factors, and under most cases, their distribution is irregular and their number is limited to a certain extent [12]. They also showed that the high cost and difficulty in covering certain regions like urban and mountainous make the interpolation process a suitable alternative for area infrastructure and services Since it is expensive and sometimes difficult to cover regions such as the mountain or urban areas, the spatial interpolation methods represent a good alternative for developing continuous spatial information based on the measured data [12].

Ly, Charles [13] reported that a host of interpolation techniques have appeared in the past, which can be categorized into deterministic and geostatistical techniques. Deterministic methods use mathematical expressions to find degree of smoothing and similarity. Like IDW, local polynomial, etc. on the other hand geostatistical techniques use statistical methods for generating spatial distribution like ordinary kriging universal kriging, etc.

Up to date, there is no a reliable method to estimate spatial distribution of rainfall because the efficiency of a given technique is affected by several variables such as nature of the surface, , size of the sample, data distribution and so forth [14].

The Erbil plain located to the southern part of the mountainous area, is characterized by having a high potential for agricultural production in case of water availability. Dry farming is practiced on a large scale over this plain, wheat, barley are the principal winter crops [15]. Keya and Karim [16] reported that the models derived for spatial events are region specific and cannot be generalized outside its region without calibration or validation. No interpolation method gives precise results in different areas and under different circumstances, each technique has its specific hydrological assumptions. Accordingly, comparison of different techniques is of vital importance to identify the best method for estimating such climatic data [12]. Further, knowledge of trends in climatic data is helpful for making better water resource management and mitigation planning in a watershed [17]. Thus, this study was initiated:

To detect trend in rainfall and evapotranspiration analysis by applying parametric and non- non parametric tests. In addition to decide the most accurate interpolation method for generating a continuous surface for rainfall and evapotranspiration across the Erbil plain and the surrounding areas.

Database and Methodologies

1. Description of the Study Area

The study area covers the southern part of Erbil province and its peripheral area spread over 12000 km^2, which is nearly 20 % of the whole area of Iraqi Kurdistan Region. It is situated between latitude 35° 43' 25.3308"and 36° 44' 54.9384" North and between longitude 44° 39' 5.0436"and 44° 36' 44.3268" East, as shown in (Fig. 1).

The altitude ranges from as low as 305 m to as high as 634 m asl. The elevation increases gradually from south to the north. The mean annual rainfall varies from a minimum 232.98 mm at Altun Kupri to a maximum of 761.39 mm at Shaqlawa. It has a unimodal distribution with rainfall mainly concentrated from October through April. There is water surplus of water from mid of November to about mid of April. Conversely, there is water deficit over the remaining period of the year. The coldest and the warmest months of the year are January and July respectively. Based on the basis of aridity proposed UNESCO [18] by the climate regime of the area under study can be classified as semiarid (0.20 < AI < 0.5). Further, most of its parts it can be classified under subhumid, mild with dry and hot summer (BSh) according to the scheme proposed by Koppen.

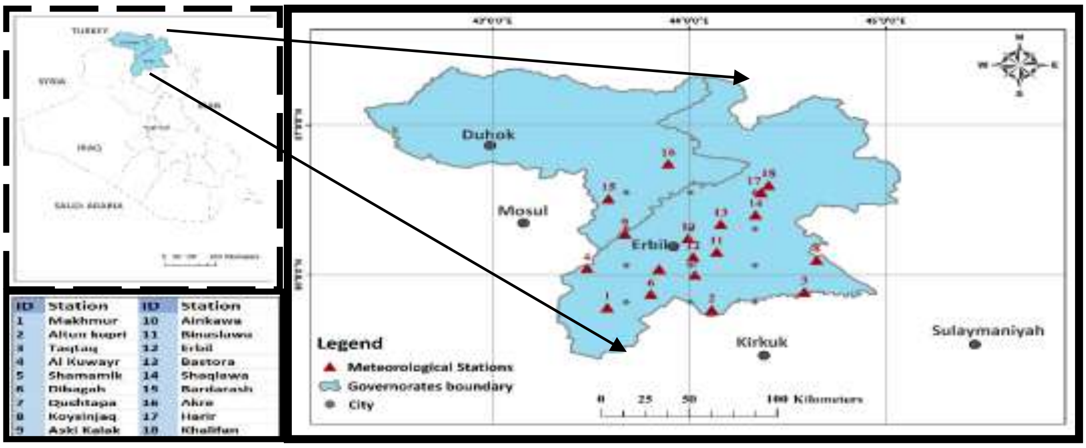


Figure 1. The meteorological stations over the study area.

2. Data Sets

The data sets encompass time series of monthly rainfall and the parameters for computing potential evapotranspiration recorded at 18 meteorological stations distributed across Erbil plan and its peripheral area. The recorded data covered a time span of 24 years (1998-2021). The collected parameters include monthly average daily maximum temperature (Tmax) , monthly average daily minimum temperature (Tmin),monthly average daily vapor pressure (ea.) , monthly average daily wind speed (u_2) and monthly average sunshine duration (n).

The obtained data were provided by the Ministry of Agricultures and Water Resources and the Directorate of Meteorology of Erbil. It is commendable to indicate some missing data was obtained from satellite.

3. Preliminary Data Analysis

The annual precipitation and potential evapotranspiration totals were determined first by summing the monthly precipitation recorded at each station. The homogeneity of the study time series was assessed by applying four tests, Pettitt test, standard normal homogeneity test (SNHT), Buishand range test (BRT) and Von Neumann ratio (VCR) at a 5% significance level for each station. The null hypothesis was accepted when test statics were less than critical value. The Shapiro-Wilk test was used for testing the normality of rainfall and evapotranspiration data.

The serial independence of the monthly and annual rainfall and ETo, were checked using the lag-1 of autocorrelation using Excel spread sheet software. In this study the modified MK (pre whitening) test was not used because the time series were not serially correlated [19]. The study time series were also checked for missing value or gaps. A few gaps were filled by using linear regression.

The formula suggested by Penman-Monteith Allen, Pereira [20] was applied to assess the potential evapotranspiration:

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma U_2 (e_s - e_a)\frac{900}{T+273}}{\Delta + \gamma(1 + 0.34U_2)} \quad \ldots\ldots(1)$$

Where ETo= potential evapotranspiration in mm day^{-1}, Δ= slope of vapor pressure against temperature (kPa $°C^{-1}$), Rn= net radiation (MJ m^{-2} day^{-1}), G= heat flux density into and out of the soil (MJ m^{-2} day^{-1}), T= average daily air temperature at a height of 2 m above the ground surface [°C], U2= wind speed at a height of 2 m above the ground surface in (m s^{-1}), e_s and e_a are saturation and actual vapor pressure respectively (kPa), γ=psychrometric constant (kPa $°C^{-1}$). It is commendable to mention that the CROPWAT software version 8.0 was used for estimation of the ET_o time series.

4. Trend Analysis

The Mann–Kendall test was used as non-parametric test to estimate the existence of statistically significant trends in rainfall and evapotranspiration data. The following expressions have been used for the Mann-Kendall test:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn(x_j - x_i) \quad \ldots\ldots (2)$$

$$Sgn\ of = \begin{cases} +1 when (x_j - x_i) > 0 \\ 0 when (x_j - x_i) = 0 \\ -1 when (x_j - x_i) < 0 \end{cases} \quad \ldots\ldots (3)$$

$$V(S) \left[\frac{n(-1)(2n+5) - \sum_{p=1}^{q} t_p (t_p - 1)(2t_p + 5)}{18}\right] \quad \ldots\ldots (4)$$

$$Z = \begin{cases} \frac{S-1}{\sqrt{V(S)}} when S > 0 \\ 0 when S > 0 \\ \frac{S+1}{\sqrt{V(S)}} when S < 0 \end{cases} \quad \ldots\ldots (5)$$

where x_i and x_j are time series observations at time i and j, n = number of observations, v = variance and tp = number of ties

The linear regression was also used in conjunction with the Mann–Kendall test to determine the magnitude of linear trend. The magnitudes of the trend in rainfall and evapotranspiration were also computed by a median after estimating slope estimator known as Theil- Sen method. The magnitude of slope (Si) was determined using:

$$Si = \frac{x_k - x_j}{k - j} \quad \text{(6)}$$

Si= Sen's slope, x_k and x_j are the values of the time series at times j and k

The median of the calculated slopes(M) was determined according to:

$$M = \begin{cases} S_{(n+1)/2} & when\, n\ is\ \ odd \\ S_{\frac{1}{2}\left[\frac{n}{2}+\frac{n+2}{2}\right]} & when\, n\ is\ \ even \end{cases} \quad \text{(7)}$$

Where n is the number of observations

5. Interpolation Schemes

During the current study, eighteen meteorological stations were interpolated spatially by employing 3 interpolation categories, namely, deterministic, geostatical and interpolation with barriers. The deterministic technique encompassed included four methods: inverse distance weighting (IDW, local polynomial interpolation (LPI), global polynomial interpolation (GPI), radial basis functions method (RBF). On the other hand, the geostatistical interpolation technique covered ordinary kriging (OK) and empirical Bayesian Kriging (EBK), while the interpolation with barriers included Kernel Smoothing (KS) and Diffusion Kernel (DK).

6. Ranking of interpolation methods

Entropy-Weighted TOPSIS Method was used for ranking of nine interpolation techniques as nine alternatives using five conflicting criteria. The criteria were: mean absolute error (MAE), mean absolute percentage error (MAPE), root mean square error (RMSE), agreement index (d) and Nash-Sutcliffe Efficiency coefficient (NSE). The weights for the above criteria were calculated by using entropy method [21].The formulas for the performance indicators or the criteria were not given because of limited space.

7. Generation of Continuous Surface for the Study Climatic Variables

The spatial maps were generated for both rainfall and potential evapotranspiration using Arc-Map version 10.8.2.

Results and Discussion

1. Descriptive Statistics of the study Time Series

1.1. Annual Rainfall Time Series

Table 1 provides the basic descriptive statistics of annual rainfall data for the selected stations over the time span of 24 years. As can be seen, the mean annual rainfall varies from a minimum of 68.55 mm at Altun Kupri in southern part to a maximum of 1464.50 mm at Shaqlawa in the northern part of the study area. overall, this parameter is characterized by being very variable. The coefficient of variation ranges between 34.42% at Shaqlawa and 48.35% at Al Kuwayr. With one exception, the annual rainfall at the study stations can be grouped under the class of high variability according to the scheme proposed by Wilding [22]. The high temporal rainfall variability in a given area makes this area more vulnerable to droughts and floods and droughts [6].

It is also apparent from the Table 1 that the annual rainfall distribution is skewed to the right or positively skewed. The majority of the stations exhibited skewness coefficient were less than or very close to 1.0, indicating that that the distribution this parameter is not highly deviated from the normal distribution. Similarly the results revealed that the that result is in line with the finding of Zakaria, Al-Ansari [23], who observed that annual rainfall fluctuate to a great extent in Sinjar area, which is situated to the west of the study area. It was also noticed that the majority of the calculated kurtosis values are positive and less than 3.0 The results obtained with Kolomogorv-Smirnov and Shapiro-Wilk tests are in agreement with the values of Skewness and Kurtosis regarding the normality of the annual rainfall recorded in study stations.

1.2 potential evapotranspiration

Unlike the annual rainfall, the potential evapotranspiration is characterized by a lower temporal variability compared to annual rainfall Table 1. The coefficient variation for the annual potential evapotranspiration at all the station is blow 5%. Like annual rainfall distribution, the potential evapotranspiration was positively skewed and the kurtosis attained positive values. The Kolmogorov-Smirnov test revealed that the annual evapotranspiration at the majority of the stations were not highly deviated from the normal distribution, but the Shapiro-Wilk test rejected that the null hypothesis at most of the study stations ($P<0.05$).

2. Detection of Inhomogeneities or Point Change in Climatic Time series

2.1. Rainfall Time Series

To detect inhomogenties in annual and monthly rainfall time series, four homogeneity tests were adopted. The tests encompassed Pettitt test, standard normal homogeneity test (SNHT), Buishand range test (BRT) and Von Neumann ratio (VCR). Table 2. Illustrates the results of the above tests applied to the annual rainfall time series recorded at 18 meteorological stations and covering during a time span of 24 years (1998-2021). As can be seen in Table 3, more that 94% of the study stations (23 stations out of 24 stations) assigned to useful class. The null hypothesis was accepted and the time series were considered to be homogeneous when the p-values were larger than a significance level of 0.05. It is also apparent that only the annual time series of Bastora station was grouped under doubtful class. According to the results, the BRT and SNHT identified breaks at the middle and the end of the time series at this station. The jump in the annual rainfall time series may be due to an abrupt increase or decrease in rainfall trend or due to relocation of the station [24]. Interestingly, with one exception, useful class can be assigned to monthly rainfall time series of the rainy season from September through May recorded at the stations (Table 3.). This implies that there is no need to correct or adjust the employed rainfall time series and they can be considered useful for further analysis.

2.2. Potential evapotranspiration (ETo)

The same homogeneity tests mentioned above were used to detect inhomogeneity or changes in on annual ETo time series and the results are presented in Table 2. As can be noticed in Table 3 the majority of the ETo time series (> 83%) were categorized under useful class. It is noticeable that no station labeled as suspect. One the other hand, Taqtaq, Aski Kalak and Ainkawa station were grouped under doubtful class. These stations are situated to middle part of the study area. It is commendable to mention that the null hypothesis was not rejected by the Pettit and BR tests at these three stations. The calculation of ETo was based several elements like temperature, wind speed, etc and there is an increased chance of uncertainties due to observing practices and instruments and relocation the stations. These data are not on hand and there is no evidence to evaluate breaks and correct the series [25]. With one exception, all the monthly ETo time series were fell under the useful time series (Table.3)

Table 1. Summary of descriptive statistics for recorded annual rainfall and evapotranspiration calculated over the study area.

Time series	Station	Minimum	Maximum	Range	Mean	Std.dev	Variance	CV(%)	Skewness	Kurtosis
Annual Rainfall	1.Makhmur	114.40	627.20	512.80	266.19	118.85	14125.48	44.65	1.27	2.34
	2.Altun Kupri	68.55	527.34	458.79	232.98	109.01	11883.88	46.79	1.05	1.69
	3.Taqtaq	155.70	878.90	723.20	395.50	153.07	23429.55	38.70	1.09	3.30
	4.Al Kuwayr	99.40	722.10	622.70	300.03	145.06	21041.42	48.35	1.31	2.10
	5.Shamamik	127.66	767.61	639.95	318.97	144.41	20855.11	45.28	1.45	3.06
	6.Dibagah	144.90	797.70	652.80	296.67	138.72	19242.69	46.76	2.10	6.64
	7.Qushtapa	102.59	681.91	579.32	299.97	124.80	15574.39	41.60	0.95	2.54
	8.Koysinjaq	238.60	1222.20	983.60	559.03	239.06	57148.22	42.76	0.96	1.12
	9.Aski Kalak	126.70	902.80	776.10	320.85	154.40	23840.49	48.12	2.30	8.41
	10.Ainkawa	193.60	963.00	769.40	382.63	157.48	24801.01	41.16	2.14	7.44
	11.Binaslawa	139.33	694.60	555.27	359.80	137.38	18872.21	38.18	0.60	0.20
	12.Erbil	114.16	640.87	526.71	328.88	129.17	16685.95	39.28	0.54	0.05
	13.Bastora	143.00	810.70	667.70	433.63	165.58	27417.89	38.19	0.25	-0.27
	14.Shaqlawa	363.50	1464.50	1101.00	761.39	262.06	68677.02	34.42	0.63	0.79
	15.Bardarash	187.14	1016.57	829.43	418.87	184.99	34222.24	44.16	1.32	3.45
	16.Akre	143.93	1425.91	1281.98	606.02	268.65	72173.41	44.33	0.91	2.57
	17.Harir	264.54	1217.20	952.66	581.41	210.33	44240.70	36.18	0.91	2.20
	18.Khalifan	263.64	1428.84	1165.20	707.29	260.80	68016.61	36.87	0.55	1.26
Annual Evapotranspiration	1.Makhmur	1692.00	1950.00	258.00	1785.25	57.02	3251.76	3.19	0.95	1.92
	2.Altun Kupri	1727.00	2018.00	291.00	1843.38	64.92	4214.94	3.52	0.77	1.03
	3.Taqtaq	1599.00	1839.00	240.00	1677.00	57.67	3326.26	3.44	1.08	1.27
	4.Al Kuwayr	1586.00	1797.00	211.00	1663.42	46.64	2175.21	2.80	0.85	1.78
	5.Shamamik	1574.00	1803.00	229.00	1661.71	50.44	2543.95	3.04	0.85	1.50
	6.Dibagah	1665.00	1920.00	255.00	1763.96	56.41	3182.22	3.20	0.80	1.34
	7.Qushtapa	1566.00	1811.00	245.00	1659.25	53.75	2888.98	3.24	0.90	1.61
	8.Koysinjaq	1534.00	1752.00	218.00	1597.88	54.57	2978.20	3.42	1.28	1.45
	9.Aski Kalak	1549.00	1838.00	289.00	1651.38	60.72	3687.46	3.68	1.14	2.77
	10.Ainkawa	1485.00	1720.00	235.00	1562.71	52.23	2727.78	3.34	1.16	2.32
	11.Binaslawa	1610.00	1835.00	225.00	1679.29	54.02	2917.69	3.22	1.25	1.71
	12.Erbil	1554.00	1805.00	251.00	1634.88	55.75	3108.38	3.41	1.24	2.56
	13.Bastora	1561.00	1778.00	217.00	1627.42	52.44	2750.25	3.22	1.24	1.63
	14.Shaqlawa	1348.00	1490.00	142.00	1394.71	33.48	1120.74	2.40	1.16	1.56
	15.Bardarash	1370.00	1602.00	232.00	1451.33	48.77	2378.49	3.36	1.12	2.74
	16.Akre	1230.00	1381.00	151.00	1278.13	33.80	1142.38	2.64	1.31	2.46
	17.Harir	1339.00	1467.00	128.00	1380.58	30.74	945.12	2.23	1.14	1.38
	18.Khalifan	1215.00	1343.00	128.00	1256.83	30.01	900.84	2.39	1.18	1.63

Table 2. Results of homogeneity tests for recorded annual rainfall and calculated evapotranspiration over the study area:

Time series	Station	N	Pettitt's test			SNHT			Buishand's test			VNR test			Classification
			K_N	P-value	K_N - critical	To	P-value	T-critical	Q	P-value	Q-critical	N	P-value	N-critical	
Annual Rainfall	1.Makhmur	24	72.000	0.133	77.00	3.467	0.414	7.23	3.384	0.582	1.46	1.417	0.075	1.35	Useful
	2.Altun Kupri	24	75.000	0.106	77.00	6.468	0.148	7.23	5.785	0.061	1.46	1.323	0.045	1.35	Useful
	3.Taqtaq	24	69.000	0.169	77.00	4.248	0.326	7.23	4.993	0.143	1.46	1.497	0.090	1.35	Useful
	4.Al Kuwayr	24	80.000	0.071	77.00	4.569	0.268	7.23	4.632	0.221	1.46	1.389	0.059	1.35	Useful
	5.Shamamik	24	81.000	0.066	77.00	3.910	0.345	7.23	4.497	0.238	1.46	1.781	0.286	1.35	Useful
	6.Dibagah	24	48.000	0.546	77.00	4.384	0.300	7.23	3.465	0.576	1.46	1.691	0.204	1.35	Useful
	7.Qushtapa	24	50.000	0.493	77.00	3.330	0.461	7.23	3.581	0.526	1.46	1.860	0.376	1.35	Useful
	8.Koysinjaq	24	51.000	0.470	77.00	3.117	0.501	7.23	3.588	0.521	1.46	1.442	0.076	1.35	Useful
	9.Aski Kalak	24	53.000	0.420	77.00	5.740	0.204	7.23	4.342	0.273	1.46	1.624	0.148	1.35	Useful
	10.Ainkawa	24	56.000	0.368	77.00	3.068	0.476	7.23	3.209	0.670	1.46	1.617	0.147	1.35	Useful
	11.Binaslawa	24	68.000	0.166	77.00	3.529	0.453	7.23	4.038	0.372	1.46	1.747	0.258	1.35	Useful
	12.Erbil	24	50.000	0.492	77.00	4.093	0.343	7.23	3.615	0.510	1.46	1.458	0.082	1.35	Useful
	13.Bastora	24	83.000	0.055	77.00	6.429	0.086	7.23	6.143	0.046	1.46	1.217	0.024	1.35	Doubtful
	14.Shaqlawa	24	44.000	0.638	77.00	2.561	0.620	7.23	2.984	0.723	1.46	1.801	0.314	1.35	Useful
	15.Bardarash	24	43.000	0.670	77.00	3.334	0.444	7.23	3.034	0.722	1.46	1.543	0.123	1.35	Useful
	16.Akre	24	36.000	0.835	77.00	3.637	0.408	7.23	2.638	0.853	1.46	2.034	0.532	1.35	Useful
	17.Harir	24	62.000	0.258	77.00	3.661	0.413	7.23	4.163	0.352	1.46	1.589	0.156	1.35	Useful
	18.Khalifan	24	54.000	0.406	77.00	5.838	0.188	7.23	4.537	0.242	1.46	1.411	0.063	1.35	Useful
Annual Evapotranspiration	1.Makhmur	24	38.000	0.795	77.00	3.537	0.365	7.23	2.527	0.866	1.46	1.864	0.363	1.35	Useful
	2.Altun Kupri	24	44.000	0.631	77.00	2.235	0.763	7.23	2.911	0.758	1.46	1.959	0.457	1.35	Useful
	3.Taqtaq	24	35.000	0.858	77.00	3.555	0.426	7.23	2.608	0.839	1.46	2.037	0.530	1.35	Useful
	4.Al Kuwayr	24	43.000	0.660	77.00	2.857	0.636	7.23	2.415	0.892	1.46	1.866	0.362	1.35	Useful
	5.Shamamik	24	45.000	0.615	77.00	3.013	0.522	7.23	2.382	0.902	1.46	1.823	0.322	1.35	Useful
	6.Dibagah	24	44.000	0.631	77.00	3.023	0.565	7.23	2.392	0.906	1.46	1.838	0.339	1.35	Useful
	7.Qushtapa	24	42.000	0.692	77.00	3.153	0.504	7.23	2.524	0.876	1.46	1.779	0.288	1.35	Useful
	8.Koysinjaq	24	39.000	0.762	77.00	4.900	0.186	7.23	3.062	0.698	1.46	1.812	0.312	1.35	Useful
	9.Aski Kalak	24	36.000	0.840	77.00	4.276	0.266	7.23	2.860	0.768	1.46	1.755	0.272	1.35	Useful
	10.Ainkawa	24	35.000	0.855	77.00	3.749	0.389	7.23	2.678	0.830	1.46	1.708	0.230	1.35	Useful
	11.Binaslawa	24	43.000	0.676	77.00	3.332	0.452	7.23	2.525	0.866	1.46	1.856	0.351	1.35	Useful
	12.Erbil	24	36.000	0.840	77.00	3.769	0.380	7.23	2.685	0.816	1.46	1.717	0.240	1.35	Useful
	13.Bastora	24	46.000	0.586	77.00	2.749	0.613	7.23	2.594	0.849	1.46	1.958	0.447	1.35	Useful
	14.Shaqlawa	24	37.000	0.806	77.00	3.749	0.382	7.23	2.678	0.825	1.46	1.934	0.441	1.35	Useful
	15.Bardarash	24	37.000	0.811	77.00	4.530	0.236	7.23	2.944	0.737	1.46	4.613	0.644	1.35	Useful
	16.Akre	24	40.000	0.733	77.00	5.522	0.129	7.23	3.250	0.633	1.46	1.605	0.160	1.35	Useful
	17.Harir	24	38.000	0.787	77.00	3.836	0.368	7.23	2.709	0.804	1.46	1.848	0.350	1.35	Useful
	18.Khalifan	24	38.000	0.787	77.00	3.890	0.372	7.23	2.728	0.805	1.46	1.888	0.383	1.35	Useful

Table 3. Classification of rainfall and evapotranspiration time series based on common homogeneity tests

Time series	Station	Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Annual Rainfall	1.Makhmur	Useful	Useful	Useful	Useful	Useful	Useful	Suspect	Useful	Suspect	Useful	Useful	Useful	Useful
	2.Altun Kupri	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Suspect
	3.Taqtaq	Useful	Useful	Useful	Useful	Useful	Useful	Suspect	Useful	Suspect	Useful	Useful	Doubtful	Useful
	4.Al Kuwayr	Useful	Useful	Useful	Useful	Useful	Useful	Suspect	Useful	Useful	Useful	Useful	Useful	Useful
	5.Shamamik	Useful	Useful	Useful	Useful	Useful	Useful	Suspect	Useful	Useful	Useful	Useful	Useful	Useful
	6.Dibagah	Useful	Useful	Useful	Useful	Useful	Useful	Suspect	Useful	Suspect	Useful	Useful	Useful	Useful
	7.Qushtapa	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Suspect	Useful	Useful	Useful	Useful	Useful
	8.Koysinjaq	Useful	Useful	Useful	Useful	Useful	Useful	Suspect	Useful	Useful	Useful	Useful	Useful	Useful
	9.Aski Kalak	Useful	Useful	Useful	Useful	Useful	Useful	Suspect	Useful	Suspect	Useful	Useful	Useful	Useful
	10.Ainkawa	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Suspect	Suspect	Useful	Useful	Useful	Useful
	11.Binaslawa	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Suspect	Suspect	Useful	Useful	Useful	Useful
	12.Erbil	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Suspect	Suspect	Useful	Useful	Useful	Useful
	13.Bastora	Doubtful	Useful	Useful	Useful	Useful	Useful	Suspect	Suspect	Suspect	Useful	Useful	Useful	Useful
	14.Shaqlawa	Useful	Useful	Useful	Useful	Useful	Useful	Suspect	Suspect	Useful	Useful	Useful	Useful	Useful
	15.Bardarash	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Suspect	Useful	Useful	Useful	Useful
	16.Akre	Useful	Useful	Useful	Useful	Useful	Useful	Doubtful	Suspect	Suspect	Useful	Useful	Useful	Useful
	17.Harir	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Suspect	Useful	Useful	Useful	Useful	Useful
	18.Khalifan	Useful	Useful	Useful	Useful	Useful	Useful	Useful		Useful	Useful	Useful	Suspect	Useful
Annual Evapotranspiration	1.Makhmur	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful
	2.Altun Kupri	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful
	3.Taqtaq	doubtful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful
	4.Al Kuwayr	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful
	5.Shamamik	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Doubtful	Useful	Useful	Useful	Useful
	6.Dibagah	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Doubtful	Useful	Useful	Useful	Useful
	7.Qushtapa	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Doubtful	Useful	Useful	Useful	Useful
	8.Koysinjaq	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Doubtful	Useful	Useful	Useful	Useful
	9.Aski Kalak	doubtful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful
	10.Ainkawa	doubtful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Doubtful	Useful	Useful	Useful	Useful
	11.Binaslawa	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Doubtful	Useful	Useful	Useful	Useful
	12.Erbil	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful
	13.Bastora	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful
	14.Shaqlawa	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful
	15.Bardarash	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful
	16.Akre	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful
	17.Harir	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful
	18.Khalifan	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful	Useful

Table 4. Serial correlation coefficients for the rainfall and evapotranspiration time series obtained over the study area

Time series	Station	Lag -1 auto correlation	t_{SCR}	$t_{v, 1-a/2}$	Serially correlated
Annual Rainfall	1.Makhmur	0.243	1.174	2.074	NO
	2.Altun Kupri	0.323	1.601	2.074	NO
	3.Taqtaq	0.222	1.068	2.074	NO
	4.Al Kuwayr	0.271	1.321	2.074	NO
	5.Shamamik	0.071	0.336	2.074	NO
	6.Dibagah	0.114	0.537	2.074	NO
	7.Qushtapa	0.067	0.314	2.074	NO
	8.Koysinjaq	0.258	1.255	2.074	NO
	9.Aski Kalak	0.176	0.838	2.074	NO
	10.Ainkawa	0.149	0.704	2.074	NO
	11.Binaslawa	0.039	0.185	2.074	NO
	12.Erbil	0.247	1.193	2.074	NO
	13.Bastora	0.374	1.891	2.074	NO
	14.Shaqlawa	0.070	0.329	2.074	NO
	15.Bardarash	0.208	0.999	2.074	NO
	16.Akre	-0.101	0.475	2.074	NO
	17.Harir	0.194	0.928	2.074	NO
	18.Khalifan	0.281	1.372	2.074	NO
Annual Evapotranspiration	1.Makhmur	0.132	0.625	2.074	NO
	2.Altun Kupri	0.171	0.816	2.074	NO
	3.Taqtaq	0.273	1.331	2.074	NO
	4.Al Kuwayr	0.085	0.400	2.074	NO
	5.Shamamik	0.152	0.723	2.074	NO
	6.Dibagah	0.165	0.785	2.074	NO
	7.Qushtapa	0.168	0.801	2.074	NO
	8.Koysinjaq	0.218	1.050	2.074	NO
	9.Aski Kalak	0.271	1.320	2.074	NO
	10.Ainkawa	0.292	1.431	2.074	NO
	11.Binaslawa	0.236	1.140	2.074	NO
	12.Erbil	0.292	1.430	2.074	NO
	13.Bastora	0.236	1.137	2.074	NO
	14.Shaqlawa	0.049	0.232	2.074	NO
	15.Bardarash	0.270	1.314	2.074	NO
	16.Akre	0.081	0.381	2.074	NO
	17.Harir	0.060	0.281	2.074	NO
	18.Khalifan	0.041	0.193	2.074	NO

Table 5. Parametric and non-parametric test results for trend analysis of recorded annual rainfall and calculated evapotranspiration in the study area

Time series	Station	S	Var(S)	Z	p-value (Two tailed)	Sen's slope (Q)	Regression Slope
Annual Rainfall	1.Makhmur	-37	1625.333	-0.893	0.359	-3.361	-0.848
	2.Altun Kupri	82	1625.333	2.009	0.045	6.593	7.520
	3.Taqtaq	72	1625.333	1.761	0.078	6.562	7.578
	4.Al Kuwayr	-28	1625.333	-0.670	0.503	-2.954	-1.625
	5.Shamamik	-56	1625.333	-1.364	0.172	-5.682	-3.444
	6.Dibagah	-14	1625.333	-0.322	0.747	-0.888	2.361
	7.Qushtapa	12	1625.333	0.273	0.785	1.129	3.595
	8.Koysinjaq	26	1625.333	0.620	0.535	6.563	6.687
	9.Aski Kalak	26	1625.333	0.620	0.535	2.314	5.922
	10.Ainkawa	30	1625.333	0.719	0.472	3.569	5.696
	11.Binaslawa	-44	1625.333	-1.067	0.286	-4.563	-3.168
	12.Erbil	-10	1625.333	-0.223	0.823	-1.022	0.738
	13.Bastora	48	1625.333	1.166	0.244	6.414	6.963
	14.Shaqlawa	14	1625.333	0.322	0.747	2.286	5.389
	15.Bardarash	22	1625.333	0.521	0.602	2.073	5.358
	16.Akre	-22	1625.333	-0.521	0.602	-3.066	1.228
	17.Harir	56	1625.333	1.364	0.172	5.500	9.161
	18.Khalifan	42	1625.333	1.017	0.309	11.054	12.566
Annual Evapotranspiration	1.Makhmur	-12	1625.333	-0.273	0.785	-0.357	0.150
	2.Altun Kupri	-32	1623.333	-0.769	0.442	-1.710	-1.014
	3.Taqtaq	-26	1625.333	-0.620	0.535	-1.721	-0.681
	4.Al Kuwayr	3	1619.667	0.050	0.960	0.000	0.487
	5.Shamamik	3	1624.333	0.050	0.960	0.063	0.247
	6.Dibagah	-3	1624.333	-0.050	0.960	-0.117	0.133
	7.Qushtapa	-2	1625.333	-0.025	1.000	0.013	0.158
	8.Koysinjaq	-23	1624.333	-0.546	0.585	-0.882	-0.567
	9.Aski Kalak	-27	1622.333	-0.646	0.519	-0.582	0.294
	10.Ainkawa	-19	1624.333	-0.447	0.655	-0.608	-0.101
	11.Binaslawa	-12	1623.333	-0.273	0.785	-0.739	-0.243
	12.Erbil	-14	1625.333	-0.322	0.747	-0.437	0.040
	13.Bastora	-14	1623.333	-0.323	0.747	-0.693	-0.230
	14.Shaqlawa	-18	1623.333	-0.422	0.673	-0.366	-0.106
	15.Bardarash	-3	1624.333	-0.050	0.960	-0.272	0.550
	16.Akre	13	1624.333	0.298	0.766	0.500	0.268
	17.Harir	-9	1624.333	-0.198	0.843	-0.358	-0.108
	18.Khalifan	-8	1621.333	-0.174	0.862	-0.146	-0.045

3. Trend Analysis

3.1. Rainfall on Annual and Monthly Time Scales

Before going into the analysis, a preliminary study was performed to show whether the study time series were serially correlated or not and only the results of rainfall on annual scale were displayed in Table 4.

The results relevant to rainfall on monthly time scale were not shown due to limits space. Irrespective of the time scale, two tailed tests revealed that the absolute value of t-statistic was less than the critical value at V= n -2 and □/2=0.025. To further confirm the results, it was noticed that autocorrelation coefficients were situated out of the confidence range of -0.44 <r<0.36. Thus, the null hypothesis was accepted and the data left without trend free pre-whitening process and without a correction of variance.

The Mann-Kendall test was applied to analyze rainfall trends on annual and monthly time scales. Sen's slope was also applied to determine the magnitude of the trend at each station. Additionally, the regression slope as a parametric test was also determine to supports the Sen's slope results. Table 5 depicts the outcome for these tests for annual rainfall over the study area. A mix of upward and downward trend was observed at the study stations. About 39% and 61% of the existing stations exhibited downward and upward trends respectively. The majority of the trends were insignificant.

Altun Kupri exhibited a significant increasing trend at 5% significance level. Also, TaqTaq and Harir showed significant increasing trends, but significant at 10% level of significance. Contrary to these results, Govay and Karim [26] observred that annual rainfall at most of the study stations within Duhok governorate presented significant positive trend at (P≤0.05) ...Among the stations with negative trends, only Shamamik station showed a significant trend at 90% level of significance. The magnitude of trend for stations with downward trends ranged from -0.888 mm/yr at Debagah to -4.563 mm/yr at Binaslawa. On the other hand, the magnitude of trend for stations with upward trends varied from a minimum of 1.129 mm/yr at Quishtapa to a maximum of 11.054 mm/day at Khalifan.

Like the annual rainfall, the monthly rainfall had a mix of negative and positive trends and the majority of the trends were insignificant. It is interesting to note that the number of

stations with upward trends decreased for the time series of January through April. Conversely, the number of stations with increasing trends increased for the time series October through December. The sign of the regression slope was in agreement with the Sen's slope in most cases, while the differed in magnitude. MK test is inferior for serially correlated time series [3]. Thus, they should be used with cautions for trend analysis.

3.2. Potential Evapotranspiration (ETo) on Annual and Monthly Time Scales

As with rainfall analysis, the same pre-processing procedure was followed for ETo before trend analysis. Table 4 exhibits only the results of the preliminary test on annual ETo. Overall, the results indicated that both annual ETo and monthly ETo were free of serial correlation.

Like rainfall time series, the ETo exhibited a mix of downward and upward trends. Unexpectedly, the majority of the stations displayed downward trends, but no significant trend was detected for this parameter on the annual time scale (Table 5). Similarly, Govay and Karim [26] observed that evapotranspiration exhibited increasing trends at the majority of the stations within Duhok governorate. Decreased temperature due to frequent dust storms may be partially responsible for this phenomenon. It was also noticed the number of stations with increasing trends were increased during January and February and the reserve was true for the remaining rainy months. Overall, an increase in air temperature in winter months may be partially responsible for these phenomena.

On annual time scale, the magnitude of negative change in ETo ranges from as low as

0.0 at Al Kuwayr to as high as -1.72 mm/yr TaqTaq station. In the meantime, it was observed that the Akre station showed a maximum positive magnitude of 0.5 mm/yr.

4. Evaluation of Different Schemes for Interpolation

4.1. Rainfall on monthly and Annual Time Scales

A host of interpolation techniques were applied to rainfall on annual and monthly time scales to generate continuous surfaces over the study area in GIS environment. Four deterministic (IDW, GPI, RBF and LPI) and three geostatistical (SK, UK, EBK) and two barriers (DKI and KSI) techniques were evaluated using cross validation procedure and five performance indicators.

Table 6 presents five criteria (performance indicators) for selecting the best alternative or the interpolator technique for estimating annual rainfall. It is commendable to mention that the analysis was based on mean annual rainfall and monthly rainfall data from 18 stations with a time span of 24 years. The results of monthly rainfall were not shown here because of space limitation.

Table 6. Evaluation of interpolation schemes for estimating rainfall and potential evapotranspiration based on some selected performance indicators:

Time series	Interpolation scheme	Performance Indicator				
		MAE	MAPE	RMSE	d	NS
Annual Rainfall	1.IDW	70.738	13.833	89.644	0.866	0.652
	2.GPI	64.327	16.132	79.935	0.919	0.723
	3.RBF	64.292	14.074	89.325	0.864	0.655
	4.LPI	47.013	10.590	69.053	0.938	0.794
	5.SK	66.511	14.645	90.602	0.870	0.645
	6.OK	52.721	12.078	71.524	0.933	0.779
	7.EBK	51.049	11.383	72.052	0.928	0.775
	8.KS	91.616	21.502	118.594	0.612	0.391
	9.DK	55.919	12.572	75.452	0.923	0.754
Annual Evapotranspiration	1.IDW	78.744	5.225	99.712	0.849	0.628
	2.GPI	47.090	3.013	61.069	0.962	0.860
	3.RBF	75.714	5.034	91.309	0.885	0.688
	4.LPI	47.329	3.044	58.704	0.965	0.871
	5.SK	85.700	5.718	114.459	0.759	0.510
	6.OK	62.837	4.031	70.341	0.948	0.815
	7.EBK	55.388	3.597	65.847	0.951	0.838
	8.KS	103.054	6.919	130.631	0.573	0.361
	9.DK	54.658	3.528	63.817	0.956	0.848

It is evident from Table 6. The LPI technique offered the lowest value for each of MAE, MAPE and RMSE and the highest values for d and NS. Unlike the LPI, the KS, the highest value for of MAE, MAPE and RMSE and the lowest values for d and NS. It is apparent from the above results that LPI is the best interpolator for estimating rainfall , followed by EBK and OK. Luo,Taylor [27] revealed that the LPI scheme can provide finer details for rainfall when it is applied over limited areas. Conversely, the KS can be considered as the least desirable choice. Under this method the mean absolute percentage of error (MAPE) exceeded 20%. With one exception, the MAPE values for the other methods were below 15%

and close that of the LPI. In this context, the monthly rainfall data behaved like the annual rainfall data (not shown here).

To further confirm the results of interpolation analysis Order Preference by Similarity to Ideal Solution technique (TOPSIS) was also applied to for ranking the abovementioned interpolation techniques based on the same five performance indicators. the entropy method was applied for determining the weights of the criteria (Table 7).

Table 7. Weights obtained for the criteria of the study time series using Entropy method:

Climatic data	Criteria	Annual	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sept	Oct	Nov	Dec
Annual Rainfall	MAE	0.246	0.160	0.210	0.250	0.272	0.120					0.281	0.255	0.143
	MAPE	0.281	0.243	0.251	0.295	0.264	0.162					0.298	0.282	0.174
	RMSE	0.180	0.139	0.164	0.200	0.235	0.127					0.194	0.223	0.101
	d	0.084	0.137	0.109	0.073	0.049	0.181					0.059	0.055	0.176
	NS	0.208	0.322	0.267	0.182	0.179	0.409					0.167	0.184	0.406
Annual Evapotranspiration	MAE	0.219	0.159	0.175	0.234	0.261	0.235	0.214	0.204	0.200	0.177	0.193	0.199	0.173
	MAPE	0.248	0.206	0.209	0.252	0.267	0.253	0.237	0.224	0.220	0.193	0.234	0.244	0.233
	RMSE	0.262	0.222	0.256	0.279	0.298	0.321	0.297	0.250	0.201	0.183	0.192	0.225	0.201
	d	0.070	0.116	0.096	0.061	0.043	0.048	0.064	0.084	0.101	0.126	0.106	0.090	0.113
	NS	0.201	0.297	0.264	0.174	0.130	0.143	0.188	0.238	0.279	0.321	0.275	0.242	0.280

It was noticed that LPI and KS attained the largest and the lowest proximity values to the ideal solution. This implies that these two methods were ranked first and ninth respectively (Table8).

Table 8. Ranking of the interpolation schemes for estimating annual rainfall and potential evapotranspiration based on proximity value to the ideal solution: using TOPSIS algorithms

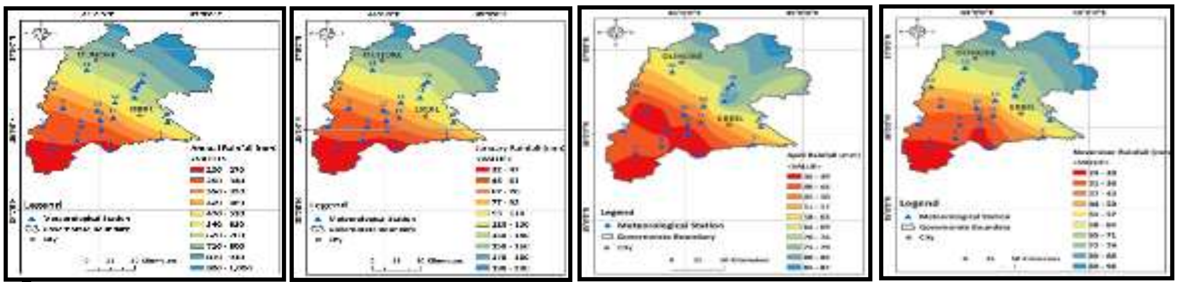
Time series	Interpolation scheme	Proximity value	Ranks
Annual Rainfall	1.IDW	0.196	6
	2.GPI	0.148	8
	3.RBF	0.199	5
	4.LPI	0.703	1
	5.SK	0.177	7
	6.OK	0.331	3
	7.EBK	0.410	2
	8.KS	0.082	9
	9.DK	0.287	4
Annual Potential Evapotranspiration	1.IDW	0.201	6
	2.GPI	0.161	8
	3.RBF	0.202	5
	4.LPI	0.707	1
	5.SK	0.180	7
	6.OK	0.342	3
	7.EBK	0.420	2
	8.KS	0.083	9
	9.DK	0.297	4

4.2. Evapotranspiration on monthly and Annual Time Scales

Like rainfall. Potential evapotranspiration on annual on monthly scales exhibited similar behavior. Judging from the performance indicators, it is obvious that the LPI and KS offered the highest and lowest performance (Table 6). The MAPE values of ETo on annual and monthly scales hardly exceeded 10%. The conclusions that were based on performance indicators and TOPSIS technique were comparable. As can be seen in Table 8, the LPI outperformed the other interpolation techniques.

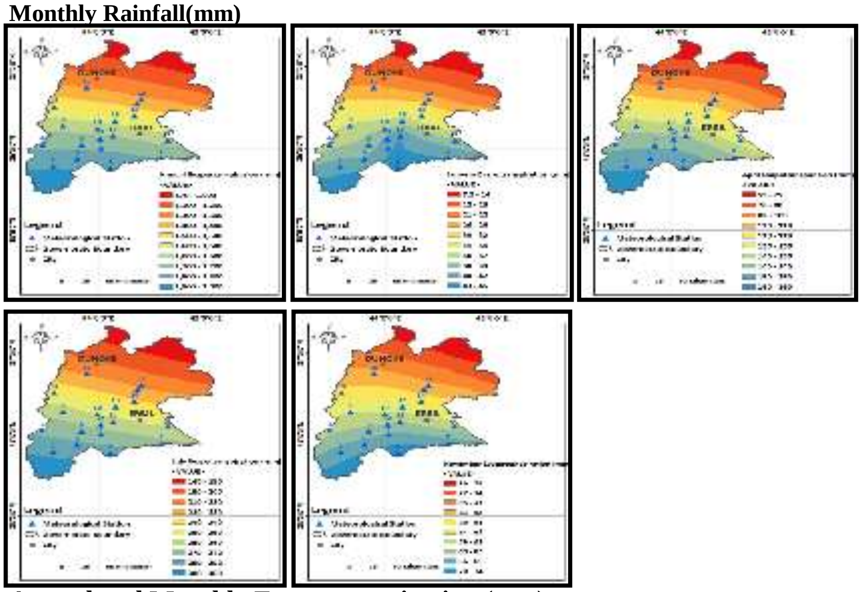
5. Spatial Distribution of Rainfall and Potential Evapotranspiration

The local polynomial interpolation method was selected to generate continuous surfaces in GIS environment for annual rainfall and potential evapotranspiration and some selected months which represent the main seasons of the year (Fig. 2). As can be noticed in Fig. 2 the annual and monthly rainfall tends to increase progressively from west to east, and from south to north. It was also observed that the potential evapotranspiration tended to decrease gradually from south to north and from west to east. Additionally, it was observed that different interpolation produced nearly similar distribution pattern (not shown here). One uses of such type of map is useful for estimating climate data at un sampled locations or to fill the gaps between the sampled locations based on the coordinates of the point of interest. Also they help to relate climatic data like ETo to the affecting input variables [28].



A

Annual and Monthly Rainfall(mm)



Annual and Monthly Evapotranspiration (mm)

Figure 2 . Spatial distribution of rainfall and evapotranspiration based on LPI method over the study area

4. Conclusions

The time series analysis of rainfall and potential evapotranspiration on monthly and annual scales indicated that the majority of the data sets are of good quality. They are not in need of inhomogeneity correction and the trend analysis does not require pre whitening process. Furthermore, the study time series have a mix of upward and downward trends. Additionally, the local polynomial interpolation (LPI) scheme was proven to be the optimal scheme for estimating the climatic data in unsampled locations over the area under study.

5. References

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التحليل الزماني والمكاني لهطول الأمطار والتبخر والنتح في سهل أربيل والمناطق الطرفية

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الملخص

تتطلب خصوصية التحاليل الحيزية الخاصة بمنطقة ما وعدم امكانية تعميمها على المناطق الاخرى البحث عن طرق الاستكمال الاكثر دقة. علاوة على ذلك فإن تحليل الاتجاهات الخاص بالمعالم المناخية ذات نطاقات زمنية مختلفة مهمة في وضع خطة أفضل للتكيف مع تغير المناخ والتخفيف من آثاره للتغلب على تفاقم شحة المياه ، وعليه تم اقتراح الدراسة الحالية للتنقيب عن اتجاهات هطول الأمطار والتبخر– النتح الكامن على نطاق شهري وسنوي في سهل أربيل والمناطق المحيطة بها باستخدام الاختبارات المعلمية واللامعلمية بالاضافة الى تقويم طرق استكمال مختلفة لتوليد الخرائط الخاصة بالمتغيرات المشار إليها. اشارت النتائج الى أن معظم السلاسل الزمنية الخاصة بالامطار والتبخر –النتح الكامن المدروسة تكون متجانسة ومستقلة تسلسليًا. كما لوحظ وجود خليط من الاتجاهات التصاعدية والتنازلية لهذه البيانات و يكون اغلبها غير احصائية على مستوى الاحتمال 5%. كما اتضحت النتائج الى كون طريقة متعدد الحدود المحلية (LPI) أفضل طريقة لتوليد خرائط للبيانات المدروسة عبر المنطقة المدروسة متبوعة بطريقة Bayesian Kriging التجريبية.

الكلمات المفتاحية: المتغيرات المناخية، تحليل الاتجاه، طرق الاستيفاء، سهل اربيل، TOPSIS .