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Quality Control of Annual Precipitation Measurement for Selected Stations in Iraq

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Abstract

In this research, quality control and homogeneity tests were performed for 20 surface meteorological stations records in Iraq. For this purpose, the annual precipitation data series at the stations of Iraqi meteorological organizations and seismology for the period (1981-2010) were considered. Quality control procedure involving outlier detection using Mandel's k method. Homogenization were analyzed by using four absolute methods tests namely SNH test, Pettitt test, BR test and VNR test, these tests were chosen to detect the inhomogeneity in data, the results of each test were evaluated at significance level 0.05. Results of Mandel's K method were classified into four categories (Normal, Abnormal 1, Abnormal 2 and Extreme) and represented in GIS software The results showed that 50% of stations were classified as Abnormal 2, 25% of stations were classified as Extreme, 20% of stations were classified as Abnormal 1 and 5% of station classified as Normal. The homogeneity tests results displayed that 5% of station assigned as "doubtful" class with break years found in 1998 for (Pettitt and BR) tests, 45% assigned as "suspect" class with break years detected for (Pettitt, SNH and BR) tests most found in 1998 and 1999 were represents 28% of break years, 21% of break years found in 1997 and other break years found between 1991-2004 and 50% of stations assigned as "useful" class.

Keywords: Quality Control (QC), Homogeneity tests, SNH test, Pettitt test, BR test, VNR test.

الخلاصة

في هذا البحث ، تم إجراء اختبارات مراقبة الجودة والتجانس الى ٢٠ سجل من المحطات الانوائية السطحية في العراق. لهذا الغرض ، تم النظر في سلسلة بيانات هطول الأمطار السنوية في محطات الهيئة العامة للانواء الجوية والرصد الزلزالي العراقية للفترة (١٩٨١-٢٠١٠). إجراء مراقبة الجودة الذي يتضمن الكشف عن القيم المتطرفة باستخدام طريقة ماندل كي. وقد تم تحليل التجانس باستخدام اختبارات الطريقة المطلقة وهي اختبار التجانس الطبيعي القياسي ، اختبار بيتيت ، اختبار مدى بويشند واختبار نسبة فون نيومان ، تم اختيار هذه الاختبارات للكشف عن عدم التجانس في البيانات ، وتم تقييم نتائج كل اختباربشكل منفصل بمستوى ثقة ٠,٠٥. نتائج طريقة ماندل كي تم تصنيفها الى اربعة اقسام (طبيعي,غير طبيعية ١, غير طبيعية ٢ ومتطرف) حيث اظهرت النتائج أن ٥٪ من المحطات تصنف على أنها طبيعي ، و ٢٠٪ من المحطات تصنف على أنها غير طبيعية ١ ، و ٢٥٪ من المحطات المصنفة على أنها متطرفة و ٥٠٪ من المحطات تم تصنيفها على أنها غير طبيعية ٢. أظهرت نتائج اختبارات التجانس أن ٥٪ من المحطات صنفت "مشكوك فيها" مع وجود سنوات كسر في (١٩٩٨) في اختبارات (بيتيت و بويشند) ، و ٥٠٪ من المحطات صنفت "مفيدة" ، والمحطات الأخرى التي تمثل ٤٥٪ صنفت "مشتبه فيها" مع سنوات كسر مكتشفة لاختبارات (التجانس الطبيعي القياسي, بيتيت وبويشند) وجدت اكثرها في (١٩٩٨ م ١٩٩٩) وبنسبة ٢٨٪ من النتائج و ٢١٪ من النتائج وجدت في (١٩٩٧) بيما وجدت سنوات الكسر الاخرى في (١٩٩١-٢٠٠٤).

Introduction

The meteorological observations data are the base to understand the variations and changes in regional and global scale of climate [1]. Also it is important to a wide range of meteorological applications , like climate modeling , climate statistic and numerical weather prediction assessment [2]. For that, it has a special importance to get better accuracy of meteorological observations, particularly surface observations data [3].

The high data quality of the climate data is the basis for the accurate climate analysis. It is also an essential to know the climate variability and extremism weather events in the condition of climate change. These analyses are important for social application, including policy making, climate change evaluation, and risk management. Getting access to good data quality data from more observation networks is becoming gradually more essential as the need to identify climate change at the local scale, for the purpose of regional climate change adaptations raises [4]. Quality control processes and homogeneity tests must be conducted prior to any data analysis in order to detect or remove erroneous values and the non-climatic changes in the time series [5]. Generally, identifying the outliers in data is one of the quality control technique. Outlier is one point or set of points that are far away from the other points that created from incorrect data measuring or extreme weather events. Many techniques which concentrate spatial and temporal variability can be used to identify the outliers whether it is erroneous or not [6]. The homogeneity tests of data series were categorized into two types as “absolute method” which applied on each station at once and “relative method” the neighbor stations (reference station) are used in the this method [7]. Several studies has been published on quality control and homogeneity tests for precipitation data series, Rashid and Shaofeng (2016), analyzed the daily temperature and precipitation data in Pakistan and India using the QC and homogeneity tests. Result showed that 0.59% of T_{max}, 0.78% of T_{min} and 0.023 of precipitation were as outliers, and (32%, 50% and 7%) for (T_{max}, T_{min} and precipitation) respectively were inhomogeneous [8]. Agha et.al, (2017), analyzed the homogeneity the precipitation data annually and seasonally records of nine stations in the northern part of Iraq with the absolute method; Pettitt, SNH, BR and VNR. The SNH test revealed that all stations were inhomogeneous and Pettitt test indicated that two stations are inhomogeneous. Seasonally, two of annual, three of winter, one of the spring precipitation data of the total stations were assessed as “doubtful” [9]. Shen et.al (2018), analyzed the daily data of (404 and 397) metrological stations for (temperature and precipitation) respectively in North of China using MASH homogeneity test method to detect the data inhomogeneity. The results show that breakpoints are present pervasively in these temperature data. Most of them appeared after 2000 [10]. In this study, outlier detection and homogeneity test were applied on 20 meteorological stations records of annual precipitation data through Iraq. The missing value of precipitation data series were completed by using spline interpolation method by GIS program. Quality control were applied by Mandel’s K statistics. Then, the inhomogeneous data detected by using absolute homogeneity tests: SNH test, Br test, Pettitt test and VNR test.

Area of study and data source

Iraq is located in southern-west part of Asia, with an estimated area of (438320 km²). Iraq is limited from the north by Turkey, Iran from the east, from the south-east with both Arabian Gulf and Kuwait, and Saudi Arabia limited it from south. The northern and southern borders of Iraq started by (37^{O} 22' N) in Kurdistan over its northern boundary with Turkey till (29^{O} 5' N) straight to the southern boundary with Saudi Arabia. Iraq started from east to the west from (38^{O} 45' E) in the Syrian desert to (48^{O} 45' E) near Shatt Al-Arab [11].

In this research, the historical records of mainly annual precipitation data were obtained from the Iraq Meteorological Organization and Seismology (IMOS) for the period (1981-2010) for precipitation. The data were collected from 20 meteorological weather stations for different location of the country as shown in table (1), Figure (1). However, the periods of these stations varies from one to another and some of them have a missing data. So, the study period was taken as long as possible in terms of data records availability.

Table 1: The meteorological station of the study.

Station	No.	Longitude	Latitude	Elevation
Rabiah	602	42.1	36.8	382
Taleafer	603	42.48	36.37	373
Sinjar	604	41.83	36.32	476
Mousl	608	43.15	36.31	223
Kirkuk	621	44.35	35.74	331
Biji	631	43.53	34.9	150
Haditha	634	42.35	34.13	140
khanaqin	637	45.38	34.35	202
Rutba	642	40.28	33.03	615
Ramadi	645	43.32	33.45	48
Baghdad	650	44.4	33.3	34
Kerblaa	656	44.05	32.57	29
Hella	657	44.45	32.45	27
Hai	665	46.03	32.13	15
Najaf	670	44.32	31.95	32
Diwaniya	672	44.95	31.95	20
Samawa	674	45.27	31.27	6
Nasiriya	676	46.23	31.02	3
Amarah	680	47.17	31.83	9
Basrah	689	47.78	30.52	2

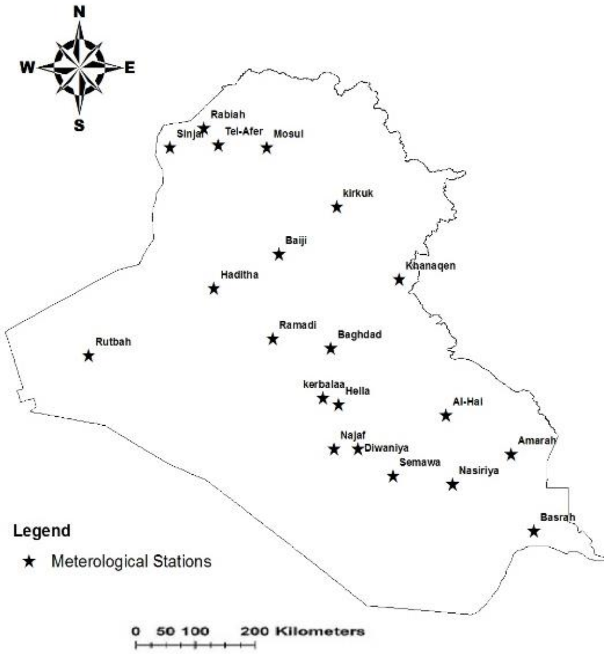

Figure 1: Meteorological stations in iraq

Materials and Methodologies

Quality control

The quality control technique used was the outlier detection for annual precipitation data using Mandel's K methods through the Xlstat program. The Mendel's method can be found by dividing the standard deviation on the square root of the sample mean [12]. Let $(s_1^2, s_2^2, \ldots \ldots s_p^2)$ is a series of *(p)* sample variances for a set of (*n*) values that observed. Assuming that the monitored values x_{ji} ; *j =1, 2, .. , p, i = 1, 2, .. n* are the realizations of randomly variables X_{ji} *w*hich are distributed in a symmetrical and independent manner according to normal distribution *N*(*μi,σ2*) for each *j*, the variances of sample S_j^2*; j = 1, 2, . , p* which is divided by their expectancies σ^2 that follow the same X_v^2/v-distribution where *ν = n−1* are the freedom degrees.

$$K_j = \frac{s_j}{\sqrt{\bar{S^2}}} \quad j=1,2,\ldots,p \tag{1}$$

$$\bar{S}^2 = \frac{1}{p}\sum_{i=1}^{p} S_i^2 \tag{2}$$

To recognize the sets which the variance is probably not in the normal state, the critical values and confidence breaks can be calculated by us for a particular level of importance about the statistic h. The formula of critical value is given by:

$$k_{p,n;1-\alpha}\sqrt{p/(1+(p-1)F_{v1,v2;\alpha}} \tag{3}$$

Where $F_{v1,v2;\alpha}$ is the quantity (*α*) of the distribution (*F*) for the freedom degree (*v1 = (p −1)(n−1)* and *v2 = n−1*) [12].

Homogeneity tests

The absolute method used to test the homogeneity for annual precipitation data including the four test. These test are Standard normal homogeneity test (SNH), Buishand range test (BR), Pettitt test and Von Neumann ratio (VNR). Taking into consideration the null hypothesis, the annual data *Yi* of the tested variables *Y* are independent with similar distribution and the series would be consider as homogeneous. While the alternative hypothesis assumes that the tests (SNH , BR and Pettitt and VNR) have a break year in the mean line of the series and will be consider as inhomogeneous. The tests (SNH, BR and

Pettitt) have the ability to find out the break that occurred in years. Also, Von Neiman Ratio test won't have the ability for giving information on the break in years because it assumes that the series are not in the random distribution under alternative hypothesis. These tests have a differences in sensitivity towards the break years that detected in the series, where SNH test detects the breaks of the series in both the beginning and the end. The tests (BR and Pettitt) are more easy to find the break of the series in the middle. Both SNH and BR tests assumes that Yi is distributed in normal form, while, Pettitt test is a non-parametric rank test so, it does not work with this assumption. The detail of these four test are explained as following:

Standard Normal Homogeneity Test

The statistic $T(k)$ defined by Alexndersson which is the comparing between the means of the first year (k) with the last year $(n-k)$ years [13]:

$$T(k) = k\bar{z}_1{}^2 + (n-k)\bar{z}_2{}^2 \quad k{=}1,.n \tag{4}$$

$$\bar{z}_1 = \frac{1}{k}\sum_{i=1}^{k}\frac{(Y_i-\bar{Y})}{s} \tag{5}$$

$$\bar{z}_2 = \frac{1}{n-k}\sum_{i=k+1}^{n}\frac{(Y_i-\bar{Y})}{s} \tag{6}$$

If the break year found in the series, then $T(k)$ would be reached the maximum values nearly to the years when $k=K$.The results of $T(k)$ is giving by figures. The statistics of the test T_o is defined as follows:

$$To{=}max_{1 \le k < n}T(k) \tag{7}$$

The test was extensively studied by Jaruskova [14], where the relationship between the statistics of the tests $T_{(n)}$ and T_o giving by:

$$T_0 = \frac{n(T(n))^2}{n-2+(T(n))^2} \tag{8}$$

The rejection of the null hypothesis happened when the value of T_o is more than the critical value. The critical values T_o depend on the size of the sample [13].

Buishand Range Test

This test is based on the adjusted partial sums or cumulative deviations through the mean [15]. The adjusted partial sum is:

$$s_0^* = 0$$

$$s_k^* = \sum_{i=1}^{k}(Y_i-\bar{Y}) \quad k = 1,2,\dots N \tag{9}$$

If the series is found as homogenous then the values of s_k^* will fluctuated nearly to the zero, because the deviations are not in regular form of the values (Y_i) with consideration to their mean appeared. If the break in year existent (K), then (s_k^*) would be reached to the maximum value (shifted negatively) or minimum (shifted positively) nearly to the year $(k=K)$. The $(\frac{s_k^*}{s})/\sqrt{n}$ is as shown in figures that represent the test results. The shift importance can be examined by the rescaled adjusted range (R) which refer to the difference of the maximum and the minimum values of (s_k^*) scaled by the standard deviation of the sample:

$$R = (max_{0\le k\le n}s_k^* - min_{0\le k\le n}s_k^*)/s \tag{10}$$

Buishand gives critical values for R/n [15].

Pettitt Test

It is none parametric rank test. Where $r_1,..,r_2$ are the rank of $Y_1\dots,Y_n$ which used the calculation of the statistics:

$$X_k = 2\sum_{i=1}^{k}r_i - k(n+1) \text{ k=1,..,n} \tag{11}$$

The X_k is showed in figures that represent the test results. If the break occurred at the year E, then the statistic will be at the maximum value near to the year $k=E$.

$$X_E = max_{1\le K\le n}|X_K| \tag{12}$$

Pettitt gives the significance level [16].

Van Neumann Ratio Test

The definition of the statistics (N) is the sequential mean square difference (year to year) [17].

$$N = \sum_{I=1}^{N-1} (Y_i - \overline{Y})^2 / \sum_{i=1}^{n} (Y_i - \overline{Y})^2 \qquad (13)$$

When N value equal to 2, this means that the sample is homogeneous, and when then the N value less than 2 then the sample has breakpoint [18]. If the variations of the mean is fast in mean, then (N) value may excess two [19]. the test doesn't give the location of the shift where occurred in the series.

Homogeneity tests classification

The results of the four tests for the rainfall series are gathered all to find the classification of the series. Schonwiese and Rapp illustrated that the classification made by the number of rejection the null hypothesis for the four tests. The explanation of the classes are [20]:

Class one: 'useful' refers to the null hypothesis is rejected by one or no test at the 5% level.

Class two: 'doubtful' refers to the null hypothesis is rejected by two tests at the 5% level.

Class three: 'suspect' class. The null hypothesis is rejected by three or four tests at the 5% level

The qualitative explanation of the classes are:

Class one: 'useful' class. There is no indication of inhomogeneity appearing in the time series. So, inhomogeneity that may be present in the series are sufficiently small with respect to the inter-annual standard deviation of the testing variable series that they will largely escape detection. The time series appears to be homogeneous for trend variability analysis.

Class two: 'doubtful' class. The inhomogeneity signal of the magnitude that exceed the level of the inter-annual standard deviation of the testing variable. The trend analysis and variability analysis results must be taken into consideration more critical from the perspective of the presence of potential inhomogeneity.

Class three: 'suspect'. The inhomogeneity is probably exist that exceeds the level expressed by standard deviation of the inter-annual testing variable. Margin results of trend and variability analysis.

Results and Discussion

The quality control of annual precipitation data were tested for 20 meteorological station using Mandel's k statistics method to detect the outlier through Xlstat program, figure (2) displayed the quality control for selected station distributes over different location in Iraq (Mosul, Rutba, Baghdad and Basrah) as an example.

The results above of Mandel's k method showed that two outliers detected in Mosul station in (January and March), also, Rutba station detected two outliers in (February and October), one outlier in Baghdad station in (January) and no outlier detected in Basrah station.

The results of Mandel's k method were represented in GIS program, where the points on the graph represent the stations of the study and the size of point depend on the numbers of the detected outliers. The results classified into:

- Normal: no outlier detected
- Abnormal 1: One outlier detected.
- Abnormal 2: Two outliers detected
- Extreme: Three or more outliers detected

Figure (6) showed the results of Mandel's k method of annual data, were 5% of station classified as Normal (Basrah) station which located in the southern part of Iraq, 20% of stations classified as Abnormal 1 which appeared in January for Baghdad and Tel-Afer, November in Alhai and Baiji, 25% of stations classified as Extreme (Rabiah, Kirkuk, Khanaqen, Ramadi and Najaf) where the outlier most found in November all station with other different monthly results and the other stations classified as Abnormal 2 where the outliers appeared in different month.

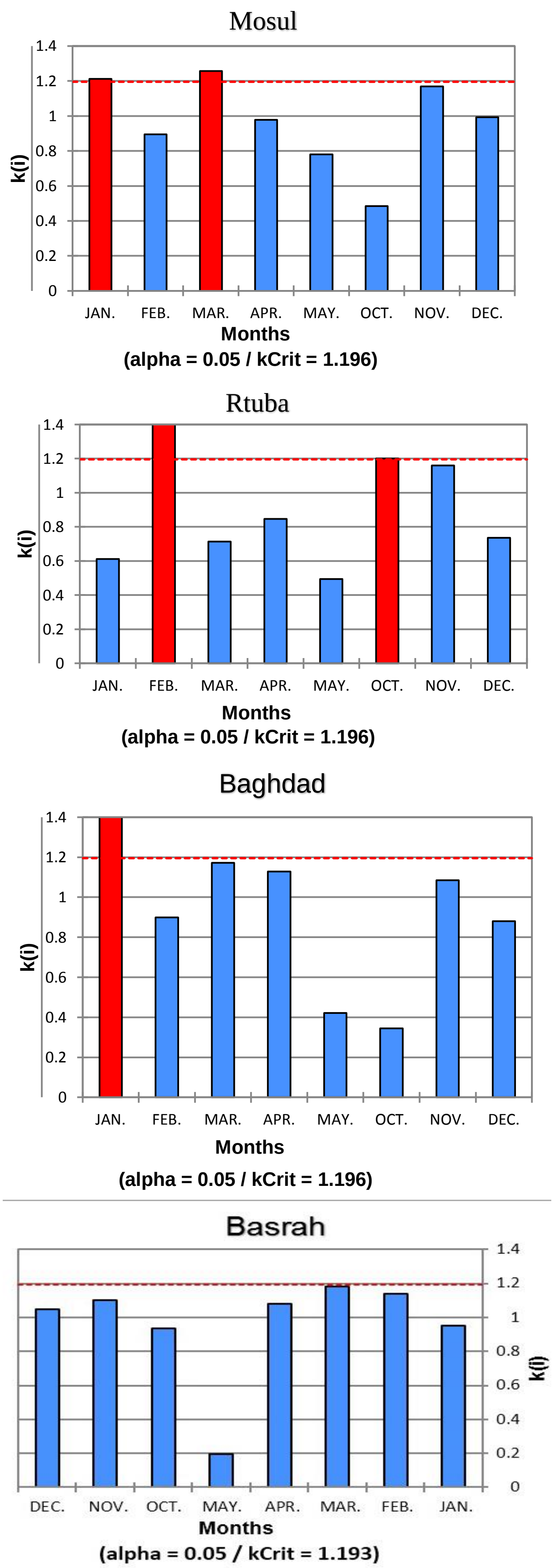

Figure 2: The detected outliers for the stations (Mosul, Rutba, Baghdad and Basrah)

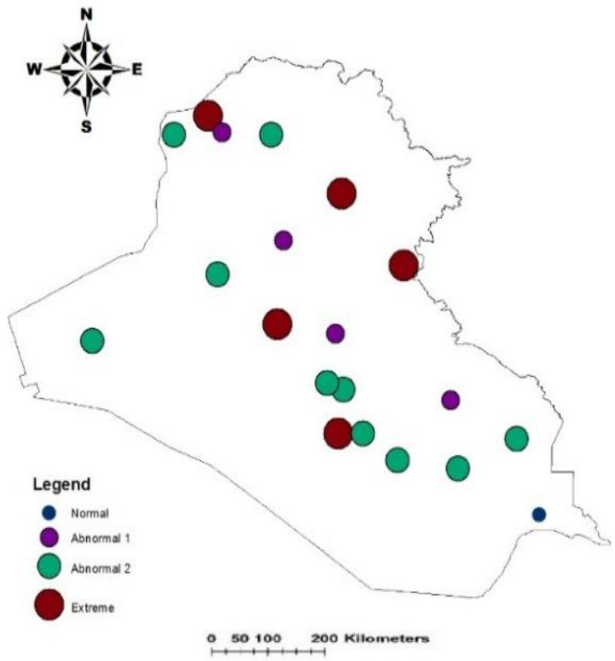

Figure 3: Classification of the detected outliers in Iraq.

The most common reasons behind outlier appearances in climate data are wrong data entry which related with the observer or instrumental errors which related with relocation, changing the instrument or may cause by delaying in frequent maintenance of instruments. Metadata availability has a big role to find out the causes of outlier appearance in the results because all station information is detailed in the station metadata. These in formation are not available at the studied stations, therefore, we do not have an evidence about the reason behind the outlier in these stations.

The homogeneity tests of annual precipitation data were tested using absolute method: SNH, Pettitt, BR and VNR tests through Xlstat program. The results were checked at significance level 0.05 depending on the p-value. Data were considered as homogeneous when the p-value is greater than 0.05 and considered as inhomogeneous when p-value less than 0.05.

Baghdad and Kerbalaa stations has been chosen as an example as shown in figures (4) and (5) to show the annual precipitation results of three homogeneity tests (Pettitt, SNH and Br) tests except VNR test doesn't give the results as a graph but only displays the data type either it is homogeneous or not because it assumes that the series is not randomly distributed under the alternative hypothesis.

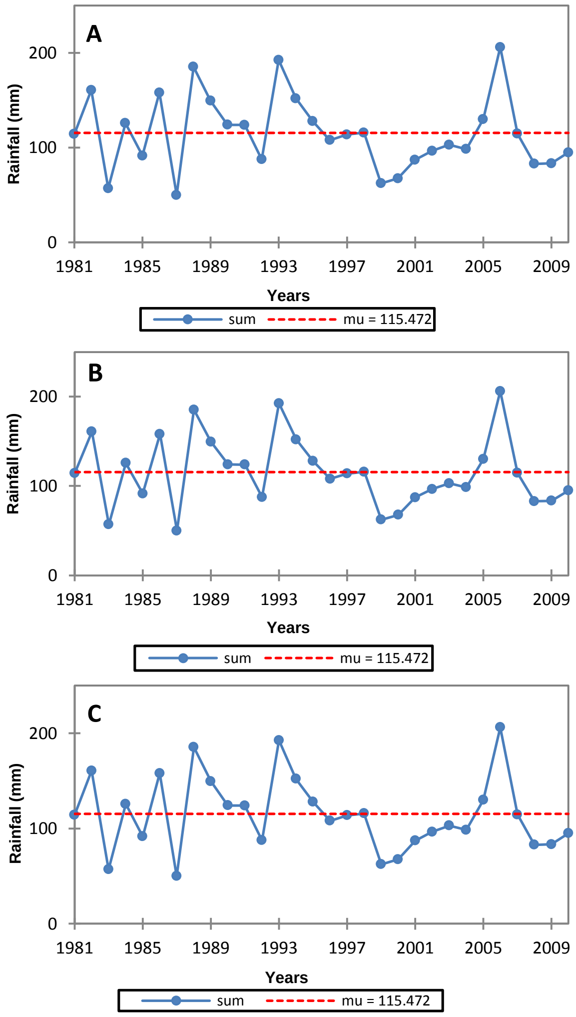

Figure 4: Homogeneity tests results for Baghdad station (homogeneous) where (A, B and C) represent (Pettitt, SNH and BR) tests respectively.

The results of homogeneity tests of Baghdad and Kerbalaa stations for annual precipitation data showed in figures (4) and (5), where Baghdad station were homogeneous time series (without and break years detected) for the three tests while the results of Kerbalaa station were inhomogeneous for the three tests with break years detected in (1999).

Schonwiese and Rapp were classified the data results of the series to: (useful, doubtful and suspect) where the classification dependent on the number of the inhomogeneity detected data from homogeneity tests results. The results of homogeneity tests for annual precipitation data represented in table (2), according to the results where 5% of station assigned as "doubtful" class (Khanaqen) station which located in the northern part of Iraq where the break years found in (1998) for (Pettitt and BR) tests, 50% of stations assigned as "useful" class for different locations of the study area, and the other stations which represent 45% assigned as "suspect" class for different locations of the study area, the results of break years detected for (Pettitt, SNH and BR) tests most found in (1998 ad 1999) were represents 28% of break years, 21% of break years found in (1997) and other break years found between (1991-2004). The spatial distribution of homogeneity test classification represented in figure (2).

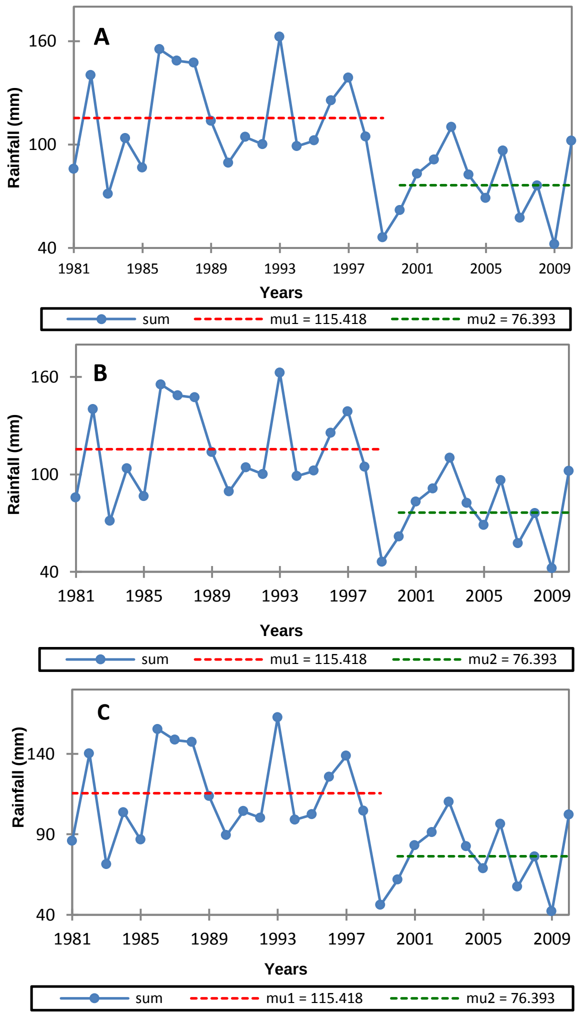

Figure 5: Homogeneity tests results for Kerbalaa station (inhomogeneous) where (A, B and C) represent (Pettitt, SNH and BR) tests respectively.

Table 2: Homogeneity tests results for annual precipitation data.

Station	Pettitt test	SNH test	BR test	VNR test	Class.
Rabiah	Homo.	Homo.	In(1997)	Homo.	Useful
Tel_afer	In(1998)	In(1997)	In(1997)	In	Suspect
Sinjar	In(1997)	In(1997)	In(1997)	Homo.	Suspect
Mosul	Homo.	Homo.	Homo.	Homo.	Useful
Kirkuk	In(1998)	Homo.	In(1998)	In	Suspect
Baiji	Homo.	Homo.	Homo.	Homo.	Useful
Rutba	Homo.	Homo.	Homo.	Homo.	Useful
Haditha	In(1999)	In(1999)	In(1999)	In	Suspect
Khanaqin	In(1999)	Homo.	In(1999)	Homo.	Doubtful
Ramadi	In(1998)	In(1998)	In(1998)	In	Suspect
Baghdad	Homo.	Homo.	Homo.	Homo.	Useful
Kerbalaa	In(1999)	In(1999)	In(1999)	In	Suspect
Hella	Homo.	Homo.	Homo.	Homo.	Useful
Alhai	In(1998)	In(1998)	In(1998)	Homo.	Suspect
Najaf	Homo.	Homo.	Homo.	Homo.	Useful
Diwania	In(2004)	In(2004)	In(2004)	In	Suspect
Semawa	In(1991)	Homo.	In(1991)	In	Suspect
Nasiriya	Homo.	Homo.	Homo.	Homo.	Useful
Amarah	Homo.	Homo.	Homo.	Homo.	Useful
Basrah	Homo.	Homo.	Homo.	In	Useful

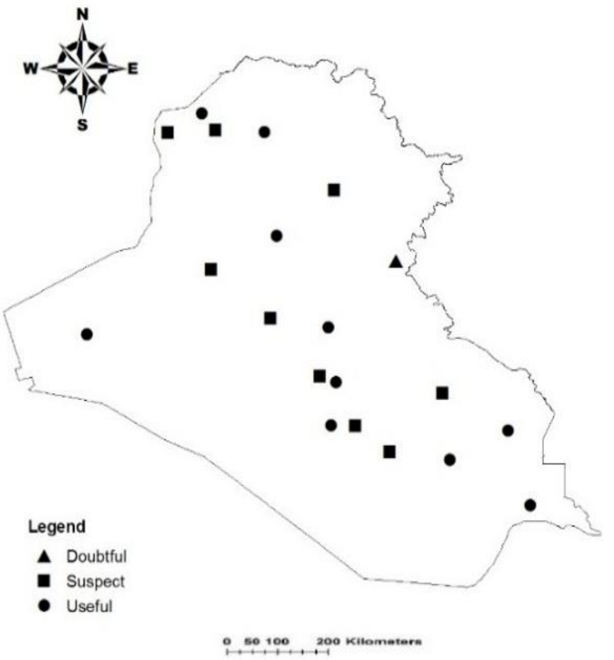

Figure 6: Homogeneity tests classification of annual precipitation data in Iraq.

The detected inhomogeneity in data may cause by either climatic reason (related with natural change in climate) or non- climatic reason which related by station relocation, surrounding environment change, instrument errors, changing observer, changing the observation procedures or data entry error. The reasons above should be mentioned in the historical metadata in detail to know the change happened in time series caused by naturally or by other factors.

Conclusion

In this study, quality control and homogeneity tests were applied on annual precipitation data. According to the results of quality control, only one station (Basrah) was classified as Normal while the others station were classified as (Abnormal 1, Abnormal 2 and Extreme) for (20, 45 and 25%) respectively.

Homogeneity tests results showed that 5% of station assigned as “doubtful” class (khanaqen), 50% of stations assigned as “useful” class and the other stations which represent 45% assigned as “suspect” class.

According to the break years detected of the homogeneity tests (Pettitt, SNH and BR) were mostly found in (1998 ad 1999) which represents 28% of break years, 21% of break years found in 1997 and other break years found between 1991-2004.

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