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CALCULATION OF THE MEAN ANNUAL RAINFALL IN IRAQ USING SEVERAL METHODS IN GIS

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Abstract

Rainfall is often utilized as a climate indicator during long dry seasons and heavy rains to define changes in the global climate. Monthly rainfall data for 36 meteorological stations of Iraq 1981–2019 were used to calculate the mean annual rainfall in Iraq over the 38 years. The mean annual rainfall was calculated based on four methods: Arithmetic, Statistical, Isoheytes, and Thiessen. The corresponding obtained values by them are 264.72, 268.48, 194.59 and 192.03 mm/year respectively. The value of 192.03 mm/year computed by Thiessen method is considered as a reliable mean annual value of rainfall for the country, because this method tries to let the non-regular distribution of gauges by providing a weighting factor for all gauges.

***Keywords* :** Rainfall, global climate, climate indicator.

Introduction

Mean annual rainfall over a region can be treated as the base parameters of the watershed modeling method, especially the processes which deal with surface runoff because the rain is the only climatic indicator that can explain fast increasing flow (Anctil *et al.*, 2006; Wheater *et al.*, 2008 and Cheng *et al.*, 2012). Rainfall plays an important role in hydrology and it is a major area in climatological studies, rainfall study is important in recognizing rainfall characteristics; duration, the variability of temporal and spatial, statistical forecasting of Rainfall, and solve the problems such drought and floods (Ayoad, 1983). In tropics, the term rainfall has acquired the place of rainfall, where snow is generally absent and rainfall is interchangeable with rainfall (Silva *et al.*, 2007). Mean annual rainfall defined as the average of a large number of years' data are essential for the development of agriculture, irrigation and many other constructions in the country (Hassan *et al.*, 1972). In hydrology, rainfall is the term for all forms of moisture emanating from clouds and falling to the ground. The rainfall is measured by gauges distributed at distance based on the vertical depth of rain that has been accumulated on land if the rainfall remained where it fell. The denser the network of gauges, the more reliable is the areal representation of mean annual (Wilson, 1970). In Iraq, we are faced with the problem of rather an inadequate network of rainfall measuring stations and also are not well uniformly distributed throughout the country. Out of this, all stations did not start at the same time and many have disquieting breaks in records, while several others ceased to function after functioning for a considerable length of time (Hassan *et al.*, 1972). In reply to increasing worry about climate change problems, investigators have started to improve techniques of evaluating the rainfall patterns and rainfall distribution. Specialists in the field of meteorological and hydrological studies need to calculate the amount of rain that falls on the station, by converting it from point rainfall data to represent the quantities that fall on the region as a whole and not on the station itself. Estimating annual rainfall is one of the processes obtainable to map the data of rainfall depended on the monthly data of rainfall. There are several kinds of methods interested in calculating the annual rainfall such as arithmetic mean, Statistical, Isoheytes, and Thiessen method. Isohyetal maps formed from this method are one of the analyses performed by most of the meteorological study (Sherman *et al.*, 1975). Later, the methods were as well carry out in another study by Fiedler (Fiedler, 2003). Another method such as the Thiessen polygon method was applied by Chidley and Keys, 1970, Singh and Birsoy, 1975, and Bayrakter *et al.*, 2005. The study by Hassan and Mashkour in 1972, showed that the mean annual rainfall in Iraq was 260 mm/year (Hassan and Mashkour, 1972). The main purpose of this study is to calculate the mean annual rainfall this done by using monthly rainfall data for 36 meteorological stations of Iraq 1981–2018 in Iraq over the 38 years. The mean annual rainfall was calculated based on four methods: Arithmetic, Statistical, Isoheytal, and Thiessen.

Materials and Methods

Study area

The Republic of Iraq is located in the South - West of Asia bordering the Arabian Gulf. It is bounded on the south by Kuwait and Saudi Arabia, on the north by Turkey, on the west by Syria and Jordan, on the east by Iran. Iraq lies between latitudes 29˚5´ and 37˚22´ North and between longitudes 38˚45´ and 48˚45´ East. The area of Iraq covers 435052.Km^2 (Al-Timimi and Al-Jiboori, 2013 and Al-Timimi and Al-Khudhairy, 2017). Iraq consisting of the Mesopotamian alluvial plain of the Tigris and the Euphrates rivers (Adeeb and Al-Timimi, 2019). The climate of Iraq is divided into three regions, which are the main Mediterranean climate region, and includes the mountainous region in the northeast. It is characterized by its cold winter, where snow falls on tops of mountains and the amount of rain ranges between 400-1000 mm annually. Its summer is mild and gentle. Temperatures do not exceed 35 degrees Celsius in most parts. The steppe climate region is a transitional climate between the Mediterranean climate and the desert climate. And the desert climate zone, which includes the sedimentary plain and the western plateau, i.e. nearly 70% of the surface of Iraq, and the annual rainfall ranges between 50-200 mm and is characterized by a great thermal range between night and day, summer and winter, where summer temperatures reach between 45-50 Celsius degree, and in winter cold weather prevails and temperatures remain above freezing and do not fall below that. Rain falls in the winter and fall seasons, and there is no summer, as the period (November-April) is considered the most humid and represents more than 90% of the annual precipitation periods, while few and sporadic rains fall in October and May. The rains vary according to the geographical regions, they decrease as we go from the northeast to the southwest, where they reach more than 700 mm in the northeastern regions of Sulaimaniyah, Shaqlawa and Dokan, and they may reach more than 1000 mm in the highlands of Zakros in the far northeast, while the average annual total precipitation is less from 100 mm in areas such as Karbala and Najaf in the southwest (Jawad *et al.*, 2018; shubbar, 1999 and Hussein *et al.*, 2007).

Methodology

In this study, monthly rainfall data from ground stations were collected from the Meteorological Organization and Seismology of Iraq (IMOS) for the years 1981 to 2019 for the 38 years. The dataset was collected from 39 stations as shown in Figure 1, also the data has been digitally encoded into an Excel database

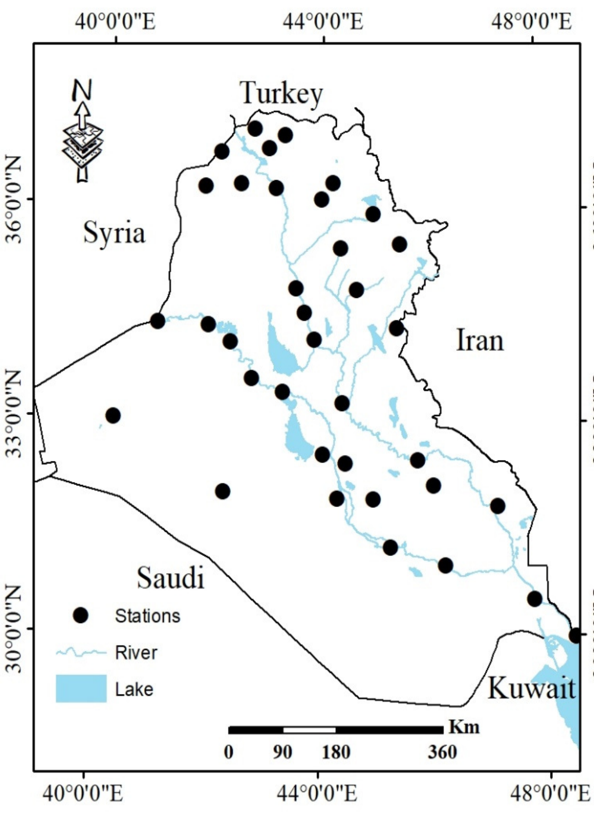

Fig. 1 : Location of meteorological stations inside the Iraq border

Geographic information system (GIS) is a computer system that collects, maintains, stores, analyzes, outputs and distributes data and spatial information. These are systems that collect spatial and descriptive information, enter it, process it, analyze it and produce it for specific goals and help in planning and decision-making, through the creation of so-called layers, this system includes the introduction of geographical information (maps and aerial photos Satellite visualizations), descriptive (names and tables), processing (incorrectly correcting), storing, retrieving, querying, spatial analysis, and statistical analysis and displaying them on a computer screen or paper in the form of maps. In GIS there are several methods to compute Mean Annual Rainfall: arithmetic mean, statistical mean, isohyetal method, and Theissen polygon network. The arithmetic mean rainfall P can be given by calculating the average of the values of the rainfall for all stations within the region. This method gives equal weight to all stations, neglected the distance and location, it should be adopted when rain gauge is uniformly distributed in a specific region.

$$P = \frac{1}{n}\sum_{i=1}^{n} P_i \qquad ...(1)$$

Where P is the rainfall at single station i, and n is the number of stations. In the Statistical distribution, even term of rainfall is multiplied by its corresponding frequency and the total sum of these products is divided by the sum of the frequencies. The Statistical mean of rainfall (P) can be given by:

$$P = \frac{\sum_{i=1}^{n} f.x}{\sum_{i=1}^{n} f} \qquad ...(2)$$

Where x is the class mark and f is the frequency.

The isohyetal method is a technique that includes drawing rainfall contour over a region based on rain gauge measurements. Then multiply the region between each line of rain equal to the average precipitation in the region to obtain the amount of precipitation in the region. Next, these volumes are summed to obtain the total precipitation volume, then the total precipitation volume is divided by the catchment area to obtain the average precipitation in the catchment. Isohyetals are lines of equal rainfall, mean of annual rainfall (P) can be given by:

$$P = \frac{\sum_{i=1}^{n} A_i P_i}{\sum_{i=1}^{n} A_i} \qquad ...(3)$$

where P_i is the average rainfall between Isohyets, Ai is the area within each isohyet.

Thiessen polygon method is a technique that calculates the weights of the meteorological station depended on the specific region of all meteorological stations in the Thiessen polygon network. Rainfall varies in intensity and duration from one place to another; hence rainfall recorded by each station should be weighed according to the area (polygons) it is assumed to influence. The individual weights are multiplied by the station observation and the values are summed to obtain the areal average precipitation. This method is also used when there are a few rain gauge stations compared to size. Thiessen method assumes linear variation of rainfall between the station and assigns each segment of the area to the nearest. Stations are drawn on the map, and link lines are drawn. Vertical equities for these connecting lines of polygons around each station. The area of each polygon was determined by GIS, then Weighted average rainfall for the total area was computed by multiplying the rainfall at each station by its assigned percentage of area and totaling. Thiessen mean annual rainfall (P) can be given by:

$$P = \frac{1}{A}\sum_{i=1}^{h} A_i.P_i \qquad ...(4)$$

Where P_i is the average rainfall at station. A_i is the area polygon.

Results and Discussion

ArcMap 10.4 was used to present the results in a GIS environment, the software was also able to calculate mean annual rainfall (mm) based on 38 years' period 1981-2019 by the four methods, arithmetic mean, statistical mean, isoheyetal method, and Theissen polygon using records of 39 observation stations. Also prepare the maps for two methods, isoheyetal and Theissen method. Arithmetic Mean was method provides the easiest way and is used in cases where the study area is a low-latitude plain region, or within the areas that are characterized by the intensity of the rainy monitoring network. This method is limited to collecting rain amounts or by collecting rain rates for all stations and dividing the result by the number of stations. The value of arithmetic mean annual rainfall in this method was 264.72 mm/year.

Table 1 shows that the rainfall data was placed in intervals, then determine the midpoint (also called a classmark) of each interval or class. These midpoints must then be multiplied by the frequencies of the corresponding classes. The sum of the products 10470.83 divided by the total number of stations 39 will be the value of the mean annual rainfall. The value of statistical method of mean annual rainfall was 268.48 mm/year. The class interval is equal to 130.4 mm/year. calculated as: Maximum annual mean of rainfall (Dukcan station 731.57mm)-minimum mean of rainfall (Nukheb station 79.57mm)/5.

Table 1 : Statistical parameters to calculate Mean annual rainfall.

Class mark x Frequency	Frequency	Classmark	Class
3329.71	23	144.77	79.57-209.97
1375.85	5	275.17	209.97-340.37
2027.85	5	405.57	340.37-470.77
1071.94	2	535.97	470.77-601.17
2665.48	4	666.37	601.17-731.57
Total=10470.83	Total=39		

In isohyetal method, rain lines of equal area are drawn, so that the effect of terrain factors, the direction of slopes, and the paths of rainstorms are taken into account so that the lines are expressive of the true rain distribution as much as possible, and then the areas between each of the two adjacent lines are measured from the lines and Calculating the average precipitation of an area in a surveyed weight method The average rainfall in each area is the average of the two rain lines that determine them, bearing in mind that this average is somewhat closer to the value of the two longest lines than to the value of the shortest line see Figure 2. Then the average rain of each region is multiplied by its area to extract the amount of rain falling on it, then all the quantities are collected and divided by the area of the whole region, so the result is the average rain of the region as shown in Table 2. The value of mean annual rainfall was 194.59 mm/year.

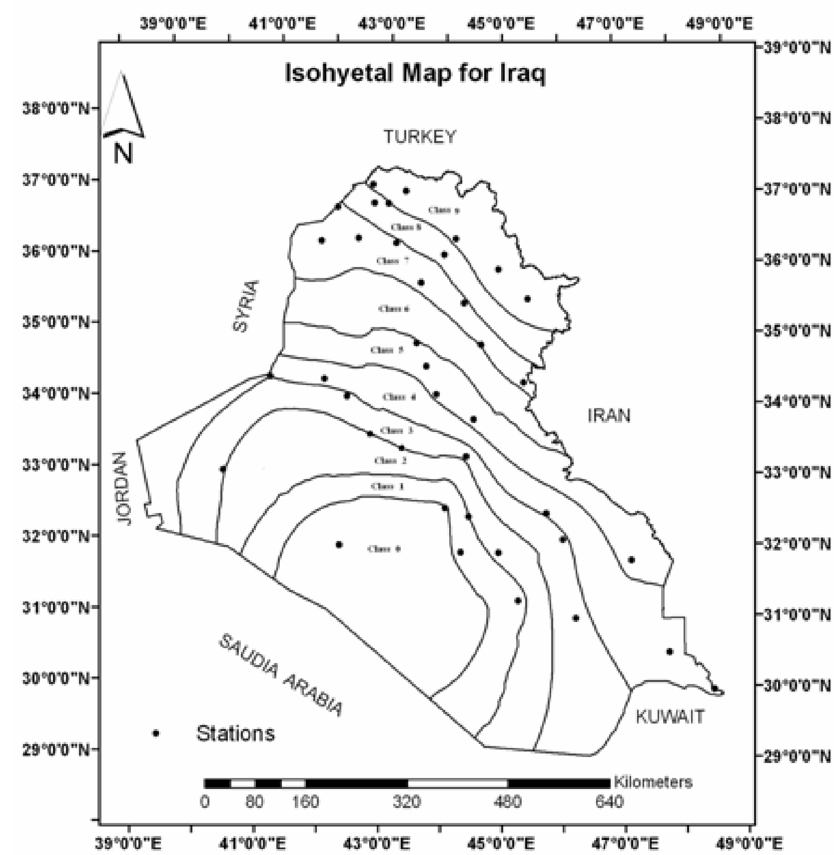

Fig. 2 : Isohyetal Map for Iraq

Table 2 : Isohytal parameters

AxP	Average Rainfall(P)mm	Area (A)	rainfall Range(mm)	Classes
530.1	85.6	6.19	79.62-91.66	0
365.1	95.5	3.82	91.66-99.42	1
588.6	105.4	5.58	99.42-111.46	2
771.0	120.8	6.38	111.46-130.14	3
893.6	144.6	6.18	130.14-159.15	4
680.0	181.7	3.74	159.15-204.18	5
729.8	239.1	3.05	204.18-274.08	6
866.8	328.3	2.64	274.08-382.58	7
802.4	466.8	1.72	382.58-551.01	8
1989.5	681.7	2.92	551.01-812.46	9
Total=8216.67		Total=42.22		

Thiessen method is the most accurate method as it is best used, and when applied it gives each station a weight that is proportional to the area it represents. To determine this area, the adjacent stations are connected by lines, then these lines are half-finished, and a column is constructed in the middle of each of them so that around each station a polygon is formed, then the area of each polygon is calculated employing a pointer or any other method, such as the squares method, then extracts the percentage of the area of each polygon to the area The total of the region, so this ratio is the "station weight". In this way, each station in the region has its weight. see Figure 3. The value of mean annual rainfall was 192.03 mm/year.

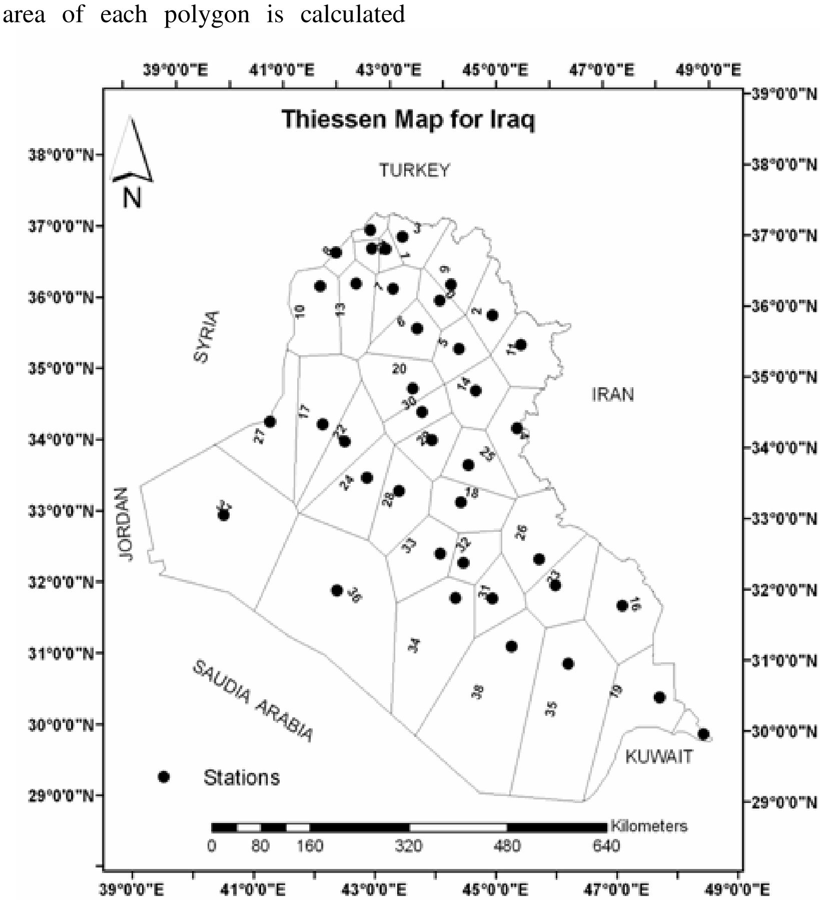

Fig. 3 : Thiessen polygon Map of Iraq

Conclusion

Mean annual rainfall is a necessary part of climatic data. Mean annual of rainfall over Iraq obtained by the Arithmetic and statistical methods were 264.72mm/year and 268.48mm/year respectively. These two methods usually are the simplest, but they yield good estimates when the average depth of rainfall wanted over a specific small area when the area concerned is flat if the rain gauges are uniformly distributed. Although the Isoheytal method is the most accurate method for averaging rainfall over an area, the value calculated as194.59mm/year by this method cannot be considered. The reason for doing so is coming due to a fact, that in an area where the number of gauges is not adequate and their distribution is not uniform, the Isoheytal can be drawn and interpreted differently. i.e. if we have a greater number and uniformly distributed rain gauges, the expected shapes of the Isoheytes will be different, consequently, the area enclosed between every two Isoheytes will vary and hence the calculated overall mean value of annual rainfall will be different from the real value. Since the thiessen method tries for non-uniform distribution of rain gauges by providing a weighting factor for each gauge, then it can be concluded that the value of 192.03 mm/year determined by this method is the most actual mean annual of rainfall in Iraq.

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