proceedings

Type of the Paper (Abstract, Meeting Report, Preface, Proceedings, etc.)

Mapping flash floods in Iraq by using GIS

Ali Raheem Al-Nassar[1], Hussain Kadhim[2]

1Department of Atmospheric Sciences, College of Science, Mustansiriyah University, Baghdad, Iraq; aliraheem@uomustansiriyah.edu.iq

2Ministry of Transportation General Company for Ports of Iraq, Iraq; hussainkadhim86@gmail.com

* Correspondence: aliraheem@uomustansiriyah.edu.iq

Abstract:

This study aims to investigate flash floods in Iraq by plotting the cartographic maps by using synoptic and dynamical analysis of meteorological reanalysis data obtains from the European Centre for Medium-Range Weather Forecasts (ECMWF) and statistical analysis of daily precipitation records from the Iraqi Meteorological and Seismology Organization for selected Iraqi stations (Mosul, Kirkuk, Khanaqin, Baghdad and Al-Rutba, Al-Hayy, Al-Nasiriyah, and Basra), as well as the use of Geographic information system (GIS) techniques. Three models create to investigate and map flash floods in Iraq. The results of the first model (The longest period of time) show that the station of Mosul record the longest period for a rainstorm, 9 days in 2014, while the lowest period was in Rutba,6 days in 2012, and the other stations varied between these two stations. The results of the second model (the highest total rainfall), present that Kirkuk station recorded the highest amount of rain (117.2 mm in 2013), while Al-Rutba station,47.2 mm in 2011, the lowest station. Finally, the results of the third model (the highest frequency of rainstorms per month) shows that the lowest frequency of rainstorms per month was in Basra,29 rainstorms in 2009, while Mosul station has 40 rainstorms in2007 and the other stations within these two values.

Keywords: flash floods, dynamical analysis, statistical analysis, GIS, cartographic maps.

Citation: Ali Raheem Al-Nassar, A.R. ;Kadhim, H. Mapping flash floods in Iraq by using GIS . *Proceedings* **2021**, 65, x. https://doi.org/10.3390/xxxxx

Received: date
Accepted: date
Published: date

1. Introduction

Rainstorms are one of the weather phenomena that occur in all parts of the world with a difference in their periods, strength and number of times. For a rainstorm to be formed, a state of atmospheric instability must be provided and an adequate amount of moisture and mechanisms to raise moist air to the upper levels in the atmosphere.

A flood occurs due to extreme precipitation or heavy rainfall accompanying severe thunderstorms, and it occurs within a short period of time, in general ranging from a few minutes to 6 hours (Hong, 2013) [1].

These floods sweep across riverbeds, agricultural lands, villages or urban areas. It is also difficult to predict or occurrence time, especially in areas where the rainfall is irregular, like Iraq [2] .

Rainfall in Iraq starts from October until the end of May, and there is no specific time to start because it is linked to the arrival of low pressures systems, its arrival time varies from season to season, to Iraq.

most of Rainfall from December through March. Although the largest number of low pressures passes over Iraq during the month of February, it is noticed that the largest amount of rain occurs during January and March, while most of the heavy rains occur in the month of November [3].

The total annual rainfall decreases from north to south (because of the rise above sea level, the south is less elevated and the north is higher) and from east to west (due to the proximity to the focus of depressions), and despite the increase in the amount of rain in some areas, a large variation in the amount of rain is observed. Not from one place to another, but in the same place from year to year, the reason for this graduation to the topographic factor, where the mountainous heights are located in the north and northeast of Iraq.

The increase in the frequency of Anticyclones is one of the main reasons for the decrease in the amounts of rainfall in Iraq [4].

Any change in the amount of rain, whether it is an increase or decrease, affects Iraq, negatively or positively. When the amount of rain falls, it leads to devastating floods, such as the floods of Iraq in the year 1963 and others in the following years, when heavy rains fell on Iraq, so there were floods in the Tigris and Euphrates rivers that They led to the destruction of some villages, as well as the destruction of agricultural crops, and many problems caused by these floods. Heavy rains lead to erosion and soil erosion. Therefore, we will address the impact of sudden heavy rainstorms on Iraq [5].

There are constant and inconstant parameters that affect the rains in Iraq, and among the constant factors are the geographical location, distance from natural water bodies, elevation, and topography of the region. For this reason, the authors did not address these factors.

As for the inconstant parameters that affect the rains, including the weather phenomena that cause heavy rainfall (cut-off lows, Rex block, jet streak and upper air trough), dynamics factors such as divergence of horizontal wind, vertical movement , the atmospheric Stability and sufficient moisture associated with heavy rainfall. Atmospheric Stability ,sufficient moisture(significant moisture) can gradually advect into Iraq from Mediterranean Sea, Red sea and the Persian Gulf, southeasterly low-level flow brings warm, moist [6]. (Ali Rahim Al-Nassar thesis)

Much of the current literature on Geographical Information System (GIS) pays particular attention to the analysis of multidimensional phenomena like natural disasters [7-11].

Romania's flood risk map for 2000,2005 and 2006 was drawn by [12] for flood events.

[13] explained that the generated map can help planners provide an intuitive way to identify the source of hazards and its dispersion throughout the domain.

In Tucuman Province (Argentina) [14] GIS to delineate the flood risk area. The use of MCDA and GIS is useful to produce flood hazard maps [7,15-16].

other researchers [17-20] trying to assess and manage water resources and floods under the potential climate changes using GIS and the analytic hierarchy process method (AHP).

In [21] flood disaster in Malaysia was studied and including the parameter distance to the river.

In this research we aim to study the synoptic situation that took place in the city of Basra on January 24, 2017, that caused the sinking of some villages, damages to the infrastructure, and the loss to agricultural crops because the level of rain reached 54 mm (more than half a meter).

We will also try to develop a spatial statistical model that simulates reality to determine and classify the strength and intensity of rainstorms through modern technologies to avoid and reduce their risks according to these classifications.

The paper is arranged as follows. Section 2 display the data sets and methodology, part 3 we examine the dynamical, and synoptic analysis and the source of humidity to the lower atmosphere of a heavy rainfall event on January 24, 2017, and part 4 identify the GIS building modules for mapping flash flood caused by heavy rainfall and their relevance for Iraq's hydrological regime, finally end with part 5 the main conclusions.

2. Data and methodology

The daily rainfall(mm) data of eight Iraqi weather stations (Mosul, Kirkuk, Khanaqin, Baghdad, Rutba, Hai, Nasiriya and Basrah (Table 1 and Figure 1) representing most parts of Iraq, for a period of 11 years—January 1, 2007 to December 31, 2017— come from the Iraqi Meteorological and Seismology Organization run by Ministry of Transport.

Administrative map of Iraq for 2019 from the General Authority for Survey run by The Ministry of Water Resources.

As for the reanalysis data, it includes geopotential height, horizontal divergence wind and vertical velocity, fields from the European Centre for Medium-Range Weather Forecasts (ECMWF) The ERA-Interim global atmospheric reanalysis, available at 1200 UTC time a day on a 0.75° × 0.75° latitude-longitude grid.

ARC GIS 10.3 program issued by the American Environmental System Research Institute (ESRI) specialized in the field of spatial analysis and production of spatial statistical models. Finally, the SPSS statistical package.

Table 1. Meteorological Stations in Iraq

	stations	**longitude**	**Latitude**	**Elevation (m)**
1	Mosul	43.09°	36.19°	223
2	Kirkuk	44.24°	35.28°	331
3	Khanaqin	45.39°	34.35°	185
4	Baghdad	44.24°	33.18°	34
5	Rutba	40.17°	33.02°	615
6	Hai	46.14°	32.08°	15
7	Nasiriya	46.14°	31.01°	3
8	Basrah	47.47°	30.31°	2.40

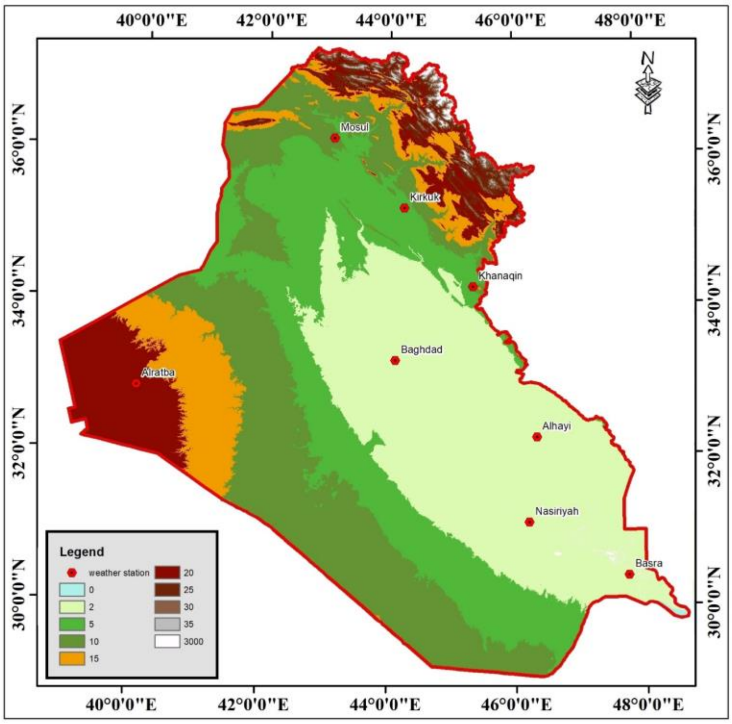

Figure 1, Physical map of Iraq according to topography and its location. It shows the location of meteorological stations that used in this study.

2.1 The Nearest Neighbor Analysis

To describe the distributions of the climatic stations in this study we use the nearest neighbor analysis. This technique produces a figure that measures the extent to which a particular pattern is clustered (nucleated), random, or regular (uniform) distribution .

the graph of the nearest neighbor analysis shows the random (clustering or regularity) distribution. The result of The nearest neighbor between 0 and 2.15. The result of the nearest neighbor analysis is equal to 1.78, and this indicates there is a tendency towards a regular pattern of weather stations and cover all parts of the study.

Section 3: Results and discussion

3.1 Synoptic and dynamic analysis of the heavy rain that fell in Basra Station on January 24, 2017.

The highest rainfall on December 22–24, 2017 (54.3 mm) in Basra city is investigated as one of the extreme event in the south of Iraq. The analysis included a day before the heavy rain with the two days in which the rainfall continued.

We investigate for this case the convective instability and dynamical forcing together with humidity sources. For convective instability, we examine the distribution of the K-index.

For dynamical forcing, we analyze the distributions of divergence of horizontal wind(s-1) with geopotential height at 250 hPa, and the Pressure vertical velocity (Pa s-1) at 700 hPa with geopotential height at 500 hPa. The geopotential line at 250 hPa and 500 hPa (fig2: a, b, c, d, e and f) present an upper level trough pattern on 23th December then get deepening by 24th December (fig 2:c, f) simultaneously with the high value of vertical velocity (fig 2: f).in the same time

We complete the analysis with K-index distribution in order to assess the instability conditions for this episode. Figure 2g, h, i clarify the evolution of the unstable conditions from the Persian Gulf and the Red Sea.

The Source of humidity were exploring through humidity and convergence of specific humidity distribution. Fig 2, j , k and l illustrated that the convergence of humidity from the Red Sea and the Persian Gulf. Therefore, a necessary condition for extreme rainfall in Iraq is the advection and convergence of humidity from the Red Sea and the Persian Gulf.

Our analysis indicates that the dynamical forced in the extreme rainfall (54.3 mm) in Basra city playing primary role and the convective instability a secondary role.

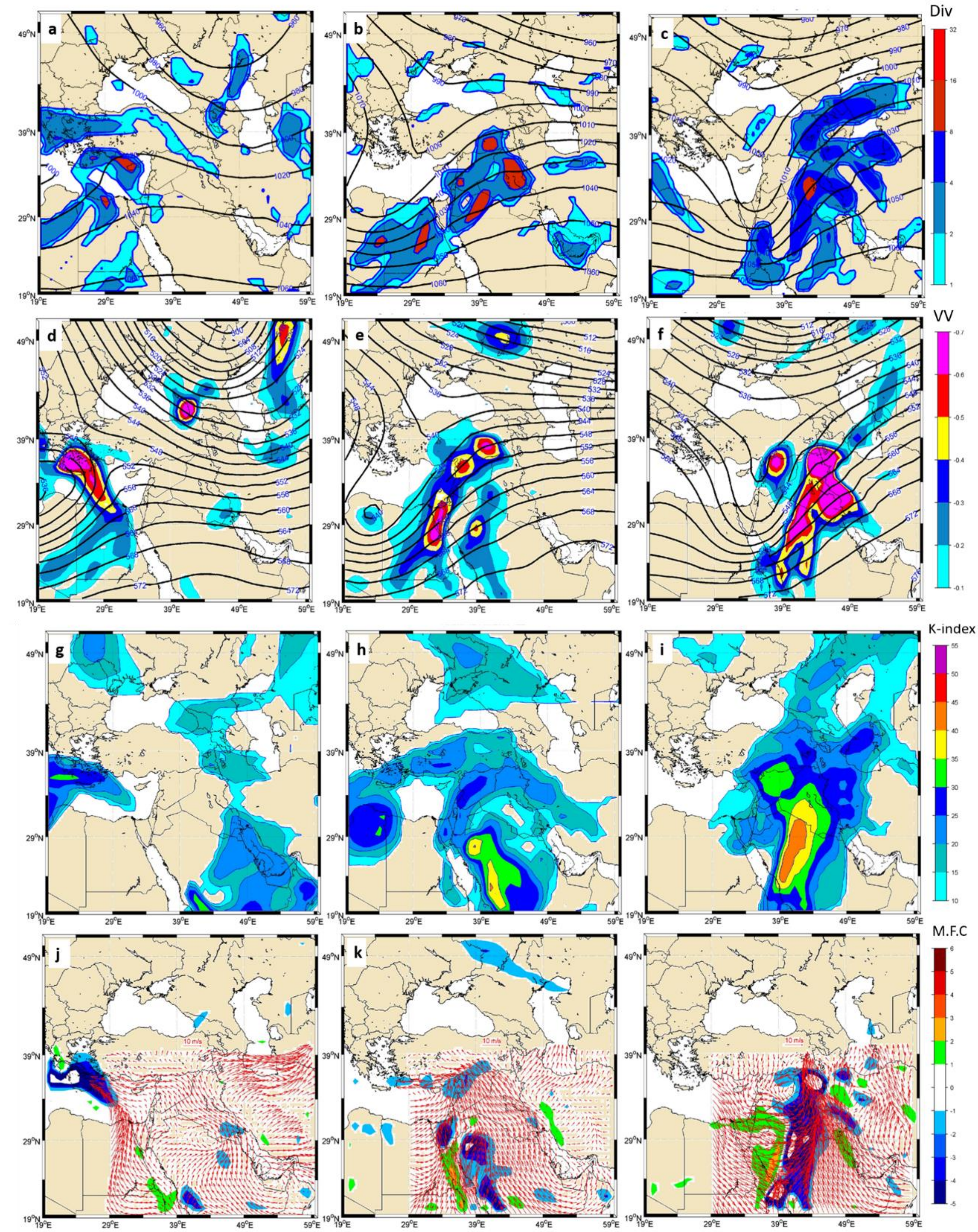

Figure 2. Dynamic conditions during extreme rainfall upper level trough over Iraq. From left to right: 22-24 January 2017, at 1200 UTC.

(First panels) Horizontal divergence (colored with intervals of 10-5 s-1) and geopotential height (black contours with intervals of 5 dam) at 250 hPa. Figure 1, a,b,c. represent 22, 23 and 24 January respectively.

(Second panels) Pressure vertical velocity (colored with intervals of 0.2 Pa s-1) at 700 hPa and geopotential height (black contours with intervals of 4 dam) at 500 hPa.

(Third panels) K index (colored, units of °C).

(Forth panels) Specific humidity content and convergence (10^{-4}g kg^{-1} s^{-1}) at 1000-850 hPa

3.2: Flash flood modelling

four models are used based on the data of the Iraqi Meteorological and Seismology Organization run by Ministry of Transport. for a period of 11 years—January 1, 2007 to December 31, 2017, for eight meteorological stations as well as using the Pearson correlation coefficient in order to determine the best model that represent the flash flood:

3.2.1: The first model:

The first model is based on the highest rainfall that fell during single rainstorm, the highest average stations are Mosul and Kirkuk in northern Iraq, while the lowest stations are in Basra and Nasiriya located in southern Iraq, indicating the gradient of isohyet extends from the north of Iraq to the lowest zone in southern Iraq, due to the elevation and latitude factors, which indicates that the northern stations are exposed to the greatest risk of a flash flood.

The results of the highest rainfall during the rainstorm show in Mosul 75.3 mm in 2013, Kirkuk 117.2 mm , as well as Khanaqin, 58.7 mm and Baghdad 89.9 mm in 2013,while in Rutba 47.2 mm in 2011, Hai station 60.3 mm in 2015, Nasiriya 75.8 mm in 2007 and finally 58.5 mm at Basra station in 2014, as shown in Table (2) and figure 3.a,b

In addition, it is noticed that the highest amount of rainfalls occurred for Khanaqin, Baghdad, Hai and Basra stations in November, and the reason is due to the activity of the Red Sea trough in this month [3].

Table 2: The highest rainfall for selected stations (2017-2007)

stations	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Average
Mosul	48.3	52.7	27.3	46.6	52.1	62.4	75.3	66.3	64.7	44.7	27.1	51.59
Kirkuk	60.6	24.7	41.2	52.3	44.7	44.4	117.2	45.3	58.9	72.4	25.2	53.35
Khanaqin	———	———	———	———	———	29.5	58.7	37.5	3.3	1.5	4.4	22.48
Baghdad	24.6	14.5	15.1	17.4	29.1	67.5	89.9	17.8	84.9	29.6	23.9	36.25
Rutba	19.9	17.3	7	41	47.2	22.5	40.6	24.1	13	8	8	22.6
Hai	13.701	21.8	23.101	20.2	30.80	23.7	32	33.802	60.3	43.602	18	29.18
Nasiriya	75.8	20.4	18.5	14.7	11.6	40.3	68.4	60.7	22.8	20.5	4.8	32.59
Basrah	40.3	18	27.8	7.7	12.2	26.2	29.6	58.5	41.6	25.6	54.3	31.07

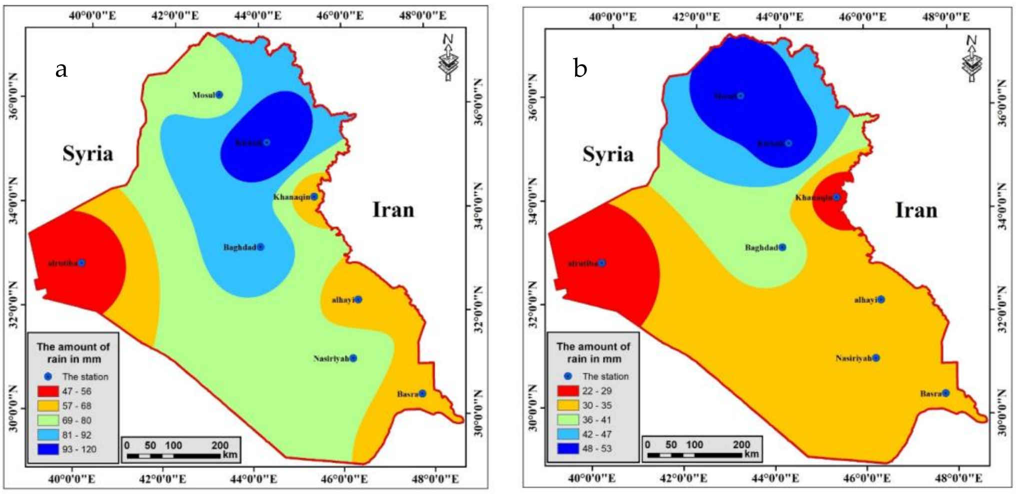

Figure 3. (a)The highest rainfall that fell during single rainstorm. (b) The average of the highest rainfall that fell during single rainstorm.

3.2.2: The second model

This model is based on calculating the average with the highest number of rainy days and rainfall records for the eight stations, and the results present that the average number of rainy days for the stations in the northern Iraq (Mosul and Kirkuk) are the rainiest days (5.9 days), while the lowest rainy days in Basra station in southern of Iraq (3 days).

In addition, the results showed that the highest number of rainy days in Mosul station are 9 rainy days with 66.3 mm Kirkuk, Kirkuk station 9 days with 38.6 mm, Khanaqin station 8 days with 7.2 mm, Baghdad station 7 with 16.7 mm, and Hay Station, 8 days, reached 33.8 mm for the year 2014. Rutba Station, 6 days, with 22.5 mm in 2012, while the Nasiriya station, 6 days, 45.9 mm, for the year 2013, and finally, the Basra Station, 6 days, in 2013, the rain reached 6.1 mm, as showed in Table (3) and figure 4.

Table 3 average with the highest number of rainy days and rainfall records and the correlation coefficient between the rainy days and the rainfall amounts.

stations		**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**Avg.**	**r***
Mosul	Days	5	6	4	7	7	6	6	9	4	6	5	5.91	0.37
	rain(mm	48.3	32.9	48	35.302	52.101	10	33.1	66.3	38	44.7	27.1	39.62	
Kirkuk	Days	5	6	5	5	7	4	7	9	6	6	5	5.91	0.27
	rain(mm)	60.6	24.3	14.6	47	32.9	24.6	117.2	38.6	40.8	10.1	25.2	39.63	
Khanaqin	Days	——	——	——	——	——	6	5	8	4	2	3	4.67	0.15
	rain(mm)	——	——	——	——	——	4.3	58.7	7.2	1	1.5	4.4	12.85	
Baghdad	Days	4	3	4	4	5	3	6	7	5	6	4	4.64	0.07
	rain(mm)	6.7	3	11	13.6	6.1	35	16.1	16.7	84.9	10.9	9.7	19.43	
Rutba	Days	2	3	2	4	5	6	4	3	3	2	3	3.36	0.41
	rain(mm)	19.9	15.8	0.01	11.8	6.3	22.5	21	7	6.2	8	0.6	10.83	
Hai	Days	4	3	3	2	3	4	7	8	5	4	3	4.18	0.46
	rain(mm)	13.7	20	23.1	10.4	1.4	8.8	17.8	33.8	22.9	43.6	1.9	17.95	
Nasiriya	Days	4	2	4	3	3	3	6	5	4	5	3	3.82	0.34
	rain(mm)	75.8	20.4	1.5	2.4	9.5	40.3	45.9	60.7	4.5	2.6	4.8	24.4	
Basrah	Days	3	2	2	3	3	3	6	2	3	2	4	3	0.46
	rain(mm)	40.3	15.7	27.8	6.4	4.3	13.8	6.1	58.5	16.8	25.6	21.4	21.52	

Note: (r*) represent Pearson correlation coefficient

The Pearson correlation coefficient between highest number of rainy days and rainfall records are calculated, the results show that all the relationships are weak positive correlation for all stations, except for the Basra station, the correlation is weak negative correlation, indicating that the increasing in the number of rainy days does not necessarily lead to an increase in the amount of rainfall amount over The study area due to the variation in the intensity of the rainstorm during its long and short duration of precipitation, which leads to the unused and neglected this model as there is no relationship between the number of highest number of rainy days and rainfall amount.

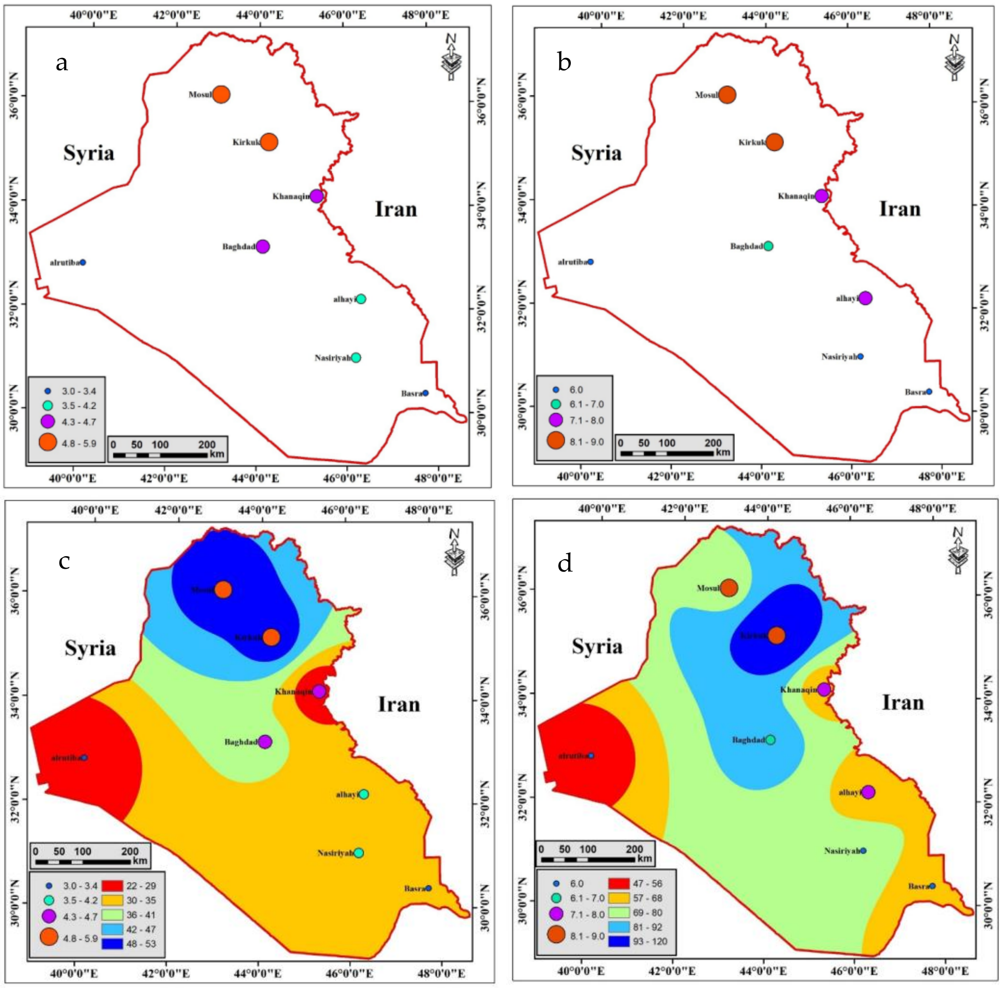

Figure 4. (a)The average of the highest number of rainy days. (b) The highest number of rainy days. (c) The average of the highest number of rainy days with rain. (d) The highest number of rainy days with rain.

3.2.3: The third model

This model is based on the highest frequency of rainstorms per month.

The results showed that the average of the highest frequency of rainstorms per month are located in the northern region of Iraq, Mosul and Kirkuk, with 6 rainstorms per month, while the lowest rainstorms are in southern of Iraq (Basra stations) as showed in Table (4) and figure 5.

In the other hand, the results of highest frequency of rainstorms per month for the period 2007-2017 showed that the highest frequency of rainstorms in Mosul and Kirkuk station, reaching **9**,8 rainstorms in 2007,2015 respectively, Khanaqin station reached 7 rainstorms in 2014, Baghdad station, 7 rainstorms for the year 2017, Al-Rutba station, 7 rainstorms in 2013, Hai Station, 6 rainstorms for the year 201, Nasiriya station, 8 rainstorms in 2017,and finally Basra station recorded 6 rainstorms in 2017.

In addition, the results indicate that the most frequent rainstorms occur in the month of March for the stations in Mosul, Kirkuk, Baghdad and Nasiriyah. As for the rest of the stations, they vary between December for each of Khanaqin and Basra stations, and the month of May for the Al-Rutba station and the neighborhood. As in the table below.

Table 4. The average with highest frequency of rainstorms and their amounts in the selected stations (2007-2017) and the correlation coefficient between the highest frequency of rainstorms and their amounts:

Station		2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Avg .	r
Mosul	Frequency	9	5	8	6	6	8	6	7	7	6	6	6.73	-0.12
	Rain(mm)	26.2	0.804	28.104	56.003	118.803	50.8	35.9	53.9	22.804	42.201	50.1	44.15	
Kirkuk	Frequency	5	5	6	6	5	7	6	7	6	6	8	6.09	0.51
	Rain(mm)	34.3	49.001	54.501	29.203	71.801	52.4	40.301	80.201	37.4	88.7	95.1	57.54	
Khanaqin	Frequency	—	—	—	—	—	4	6	7	5	4	3	4.83	0.24
	Rain(mm)	—	—	—	—	—	35.1	21	15.5	6.4	3.4	2.3	13.95	
Baghdad	Frequency	4	5	7	5	5	5	6	5	5	5	7	5.36	0.02
	Rain(mm)	32.2	23.703	11.404	5.504	25.103	83.203	70.806	35.802	28.203	30.303	42.005	35.29	
Rutba	Frequency	5	3	5	4	6	6	7	5	5	3	5	4.91	0.12
	Rain(mm)	16.3	10.5	0.703	24.501	20.805	0.206	13.91	36.502	13.603	0.001	11.002	13.46	
Hai	Frequency	5	5	5	6	5	6	6	5	5	5	6	5.36	0.01
	Rain(mm)	3.304	45.304	6.405	26.204	50.104	32.1	51.505	46.901	56.901	35.201	31.2	35.01	
Nasiriya	Frequency	5	3	4	5	6	5	6	5	6	5	8	5.27	0.15
	Rain(mm)	9.202	1.401	7.102	29.202	19.905	19.303	7.803	83.005	36.101	11.6	19	22.15	
Basra	Frequency	5	4	6	6	5	5	3	3	5	3	6	4.64	-0.06
	Rain(mm)	46.703	31.6	39.601	17.502	22.4	28.902	40.201	60	43.802	26.1	64.104	38.27	

In addition, the results of the Pearson correlation coefficient between the rate of the highest frequency of rainstorms per month and their quantities of rain in the selected stations between (2007-2017) indicate that all the relations are weak positive correlation for all stations except for Mosul and Basra stations are weak opposite correlation.

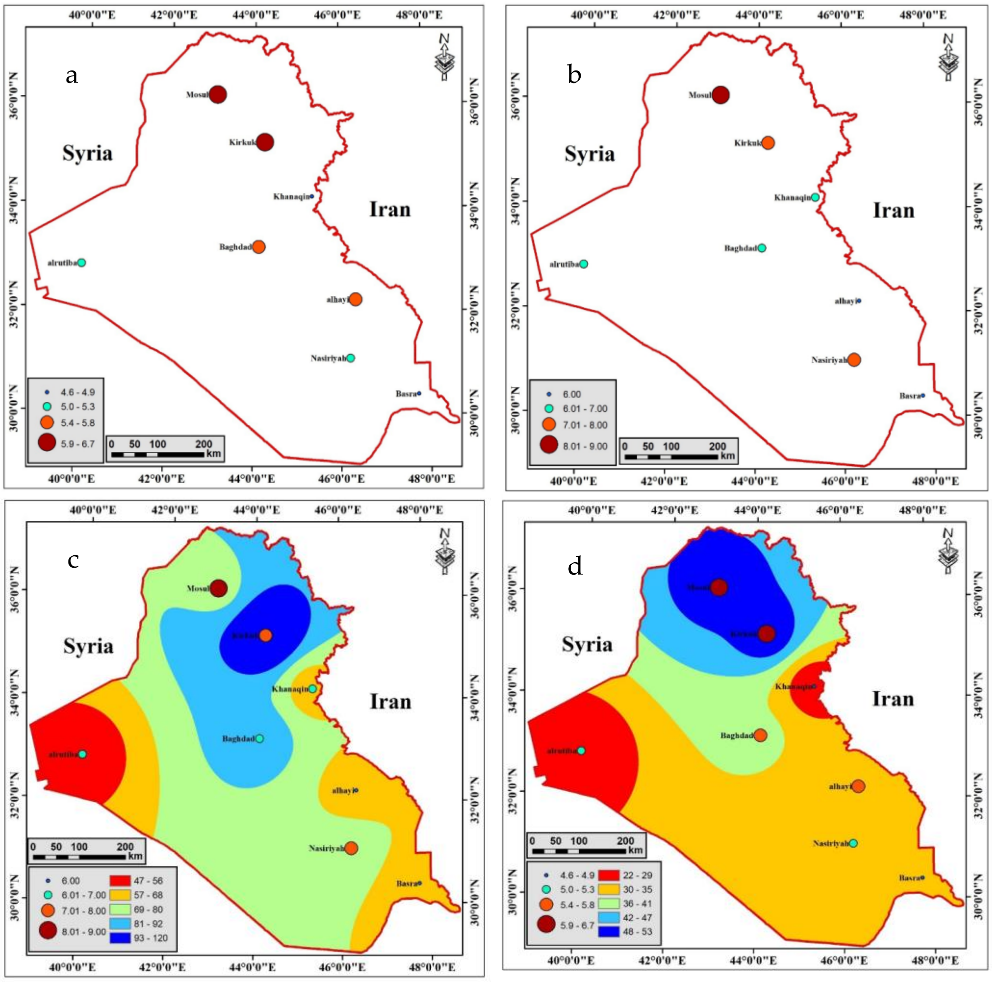

Figure 5. (a)The average of the highest frequency of rainstorms per month. (b) The highest frequency of rainstorms per month. (c) The average of the highest frequency of rainstorms per month with rain. (d) The highest frequency of rainstorms per month with rain.

3.2.4: The Fourth Model

This model is based on the total annual rainstorms with the annual rainfall amount.

The results of the mean annual total rainstorms present the highest mean in the northern region of Iraq, Mosul with 35 rainstorms per year, while the lowest mean in southern stations, Basra station with 18 rainstorms per year.

From Table 5 and figure 6, we can find that the highest rainstorms for all stations for the period 2007-2017 and it is in Mosel (41 rainstorms in 2011), and Kirkuk (40 rainstorms in 2015), while the lowest rainstorm in Basra (26 rainstorms in 2009) and the other station ranging between them: Khanaqin station (28 rainstorms in2014), Baghdad (33 rainstorms in 2009), Rutba station (33 rainstorms in 2013), Hai (30 rainstorms in 2014) and finally Nasiriya (31 rainstorms in 2014).

The Pearson correlation coefficient are calculated between the total annual rainstorms with the annual summation of rainfall. The results of the correlation coefficient are strong positive correlation for Khanaqin station 0.80, moderate positive correlation (0.4-0.7) for Basra, Nasiriya, Hai and Rutba station, while weak positive correlation for Mosul and Kirkuk station (0.23-0.28).

Finally, weak negative correlation for Baghdad station -0.002.

Table 5. The total annual rainstorms with the annual rainfall amount in the selected stations (2007-2017) and the correlation coefficient between the total annual rainstorms and the annual rainfall amount:

stations		2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Avg .	r
Mosul	Rainstorms	40	30	32	35	41	39	33	36	36	35	28	35	0.23
	Rainfall(mm)	193.8	216.318	223.815	240.616	294.718	278.61	455.513	340.811	288.809	216.007	145.103	263.1	
Kirkuk	Rainstorms	27	27	32	27	35	34	29	37	40	26	31	31.36	0.28
	Rainfall(mm)	173.106	134.916	225.814	267.212	221.81	292.105	394.305	319.008	315.505	321.504	204.504	260.89	
Khanaqin	Rainstorms	-	-	-	-	-	26	23	28	20	15	8	20	0.81
	Rainfall(mm)	-	-	-	-	-	116.4	169.35	170.3	14.9	4.9	10.1	80.99	
Baghdad	Rainstorms	20	22	33	27	27	26	27	32	29	27	30	27.27	-0.002
	Rainfall(mm)	99.214	59.119	67.524	92.519	96.021	184.422	296.725	107.524	190.923	104.522	71.829	124.58	
Rutba	Rainstorms	12	15	24	26	29	29	33	30	17	3	21	21.73	0.7
	Rainfall(mm)	58.401	72.901	23.312	109.017	87.92	73.018	135.219	157.61	41.908	10.301	21.814	71.95	
Hai	Rainstorms	21	26	27	22	24	28	27	30	28	21	21	25	0.64
	Rainfall(mm)	64.51	87.621	85.32	80.309	120.313	81.207	156.814	188.615	194.612	123.513	43.105	111.45	
Nasiriya	Rainstorms	22	17	29	20	28	24	28	31	28	24	28	25.36	0.4
	Rainfall(mm)	112.515	65.505	56.917	57.616	85.119	116.22	174.22	219.723	93.22	68.3	29.7	98.1	
Basrah	Rainstorms	23	13	29	16	21	22	14	5	19	19	17	18	0.5
	Rainfall(mm)	139.21	67.103	89.811	57.007	65.307	115.309	48.31	60.5	131.508	86.908	128.209	89.93	

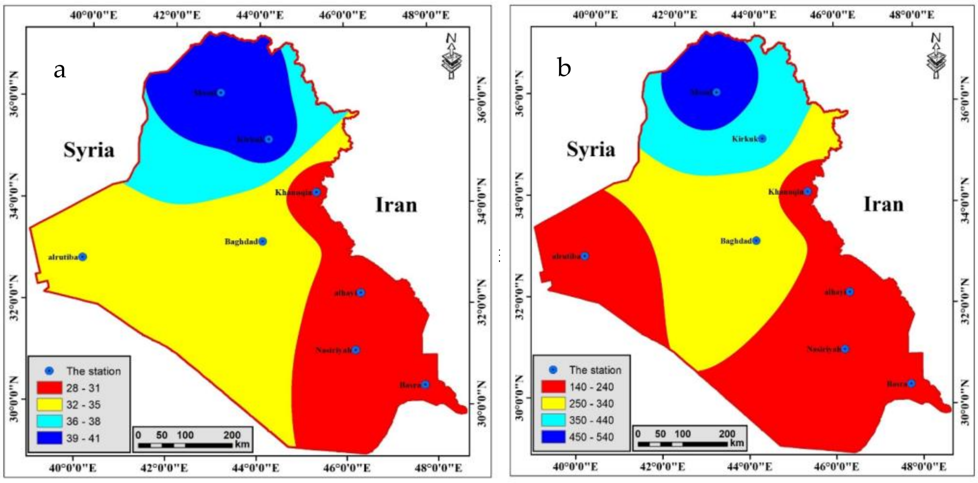

Figure 6. (a)The highest total annual rainstorms (2007-2017). (b) The highest total annual rainfall (2007-2017)

Conclusions:

flash floods have negative effects that causing material and human losses and stopping all human activities when they occur. The different characteristics of a rainstorm (quantity, intensity, duration) have the greatest influence on the negative effects of the flash floods. Also there is a set of fixed factors (geographical location, distance from waterbodies, topography) that determine the general form of the intensity of the impact of rainstorms in each Iraq's parts.

Dynamic factors (lows and highs pressures) play an important role in determining the time and characteristics of flash floods. The activity of dynamic factors serves as a warning bell for all service means to take precautions to prevent any loss of life or vital facilities within the area of occurrence. The results of the statistical analysis showed that the length of the duration of the rainstorm is not a significant factor in the formation of the flash floods, because the length of the rainstorm duration does not necessarily lead to an increase in the amount of rainfall, except in the case of its association with the strength of the rainstorm intensity (the amount of precipitation / unit time), Therefore, this model is canceled from relying on its results as one of the models that determine the locations of the effective flash floods.

The results of the statistical analysis showed that the increase in the frequency of rainstorms does not necessarily lead to an increase in the intensity of the flash floods, because this increase in the number of iterations may increase the probability of rainstorms that do not lead to the formation of flash floods to cause damages or stop the daily life of humans. The increase in (the amount of precipitation / unit time) leads to an increase in the risk of flash floods, because it reduces the chance of Infiltration, evaporation, runoff entering a storm drain or rivers.

The research proved that geographic information systems (GIS) have a tremendous ability to analyze, process and deal with various types of data (descriptive, rank, quantitative) and simulate reality based on the data entered by the researcher into the program environment, This reduces it to a lot of time, effort, and money if work in the traditional way, in addition to the fact that the accuracy granted by this technique, is characterized by being ideal and characterized by high objectivity, and this is what the researcher is looking for in such studies.

We also have assessed the synoptic conditions of one of the highest flash flood events, in Basra city taking place December 23–24, 2017. The upper (250 hPa) and middle (500 hPa) atmospheric conditions present an upper-level trough leading to this episode.

Southern Iraq (Basra city) was affected by the divergence of horizontal wind and associated with upwards motions. Simultaneously, the low-level atmosphere, experiencing the convergence of humidity from the Red Sea and the Persian Gulf. In addition, the instability condition (k-index) was only a minor role as compared with the dynamical forcing.

ACKNOWLEDGEMENTS

We are very grateful to the Mustansiriyah University (collage of science, Department of Atmospheric Sciences), General Company for Ports of Iraq and the Iraqi Meteorological and Seismology Organization for providing daily precipitation records.

We thank the European Centre for Medium-Range Weather Forecasts for making freely available the ERA-Interim reanalysis for providing the reanalysis data.

References

[1] Buchwaldt, R.;Encyclopedia of Natural Hazards, Bobrowsky,P.T, Springer Netherlands,Simon Fraser University Canada, 2013,324.

[2] NOAA, National weather service, Flood and flash flood definitions,National Oceanic and Atmospheric Administration. Available at: https://www.weather.gov/mrx/flood_and_flash, 24-06-2021.

[3] Al-Nassar, A.R. ; Pelegrí, J.L. ; Sangrà, P. ; Alarcon, M. and Jansa, A. Cut-off low systems over Iraq: Contribution to annual precipitation and synoptic analysis of extreme events. International Journal of Climatology, 2020.40(2), pp.908-926

[4] Aboud Al-Kinani, M.N.; Al-shamry, M.K. Synoptic analysis of floodwaters affecting East Wasit Governorate and its impacts on infrastructure and agricultural land, Journal of the College of Education, Wasit University, 2019, 4 ,4, DOI: https://doi.org/10.31185/eduj.Vol4.Iss4.966.
[5] Abdul-Jabbar,A.M.; Khtan ,A.Predicted the Cumulative Annual Rainfall in Iraq using SDSM Moda, Al-Mustansiriyah Journal of Science, 2021,32,2,.DOI: http://doi.org/10.23851/mjs.v32i2.97
[6] Al Nassar,A.R.T. Dynamics of Cyclones and Precipitation over the Middle East, Ph.D. Degree, Universitat Politècnica de Catalunya. Departament de Física, Spain, 25-09-2018.
[7] Vahidnia, M.H.; Alesheikh, A.A.; Alimohammadi,A.; Hosseinali, F. A GIS-based neurofuzzy procedure for integrating knowledge and data in landslide susceptibility mapping. Computers & Geosciences,2010, 36, 9: 1101–1114.
[8] Alaghmand, S.; Bin-Abdullah, R.; Abustan, I.; Vosoogh, B. GIS-based River Flood Hazard Mapping in Urban Area: A Case Study in Kayu Ara River Basin, Malaysia. International Journal of Engineering & Technology, 2010, 2, 488–500.
[9] Wang,Y.; Li, Z.; Tang, Z.; Zeng, G. A GIS-based spatial multi-criteria approach for flood risk assessment in the Dongting Lake Region, Hunan, Central China. Water Resources Management, 2011, 25, 13, 3465–3484.
[10] Patel, D.P.; Srivastava, P.K. Flood hazards mitigation analysis using remote sensing and GIS: Correspondence with town planning scheme. Water Resources Management, 2013, 27, 7, 2353–2368.
[11] Jaafari, A.; Najafi, A.; Pourghasemi, H.R.; Rezaeian, J.; Sattarian, A. A GIS-based frequency ratio and index of entropy models for landslide susceptibility assessment in the Caspian forest, northern Iran. International Journal of Environmental Science and Technology, 2014,11, 4, 909–926.
[12] Aldescu, G.C. The necessity of flood risk maps on Timis river. IOP Conference Series: Earth and Environmental Science, 2008,4. IOP Publishing.
[13] Koehler, K.A.; Volckens, J. Prospects and pitfalls of occupational hazard mapping: 'between these lines there be dragons', Annals of Occupational Hygiene, 2011,55, 8, 829–840.
[14] Fernández, D.S.; Lutz, M.A. Urban flood hazard zoning in Tucumán Province, Argentina, using GIS and Multi Criteria Decision Analysis. Engineering Geology, 2010,111, 1–4, 90–98.
[15] Sowmya, K.; John, C.M.; Shrivasthava, N.K. Urban flood vulnerability zoning of Cochin City, southwest coast of India, using Remote Sensing and GIS. Natural Hazards, 2015,75, 2, 1271–1286.
[16] Gerl, T.; Bochow, M.; Kreibich, H. Flood Damage Modeling on the basis of Urban Structure Mapping Using High-Resolution Remote Sensing Data. Water, 2014, 6, 8, 2367–2393.
[17] Emmanouloudis, D.; Myronidis, D.; Ioannou, K. Assessment of flood risk in Thasos Island with the combined use of multicriteria analysis AHP and geographical information system. Innovative Applications Information Agricultural Environment, 2008 2, 103–115.
[18] Sinha, R.; Bapalu, G.; Singh, L.; Rath, B. Flood risk analysis in the Kosi river basin, north Bihar using multi-parametric approach of analytical hierarchy process (AHP). Journal of the Indian Society of Remote Sensing, 2008,36, 4, 335–349.
[19] Meyer, V.; Scheuer, S.; Haase, D. A multicriteria approach for flood risk mapping exemplified at the Mulde river, Germany. Natural Hazards, 2009, 48, 1, 17–39.
[20] Chen, Y-R.; Yeh, C-H.; Yu, B. Integrated application of the analytic hierarchy process and the geographic information system for flood risk assessment and flood plain management in Taiwan. Natural Hazards, 2011,59, 3, 1261–1276.
[21] Tehrany, M.S.; Pradhan, B.; Jebur, M.N.; Neamah, M. Flood susceptibility mapping using a novel ensemble weights-of-evidence and support vector machine models in GIS. Journal of Hydrology, 2014,512, 332–343.