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Using CHIRPS Satellite-Based Data for Spatio-Temporal Variability of Rainfall in Dashti Hawler District – Kurdistan Region of Iraq 1982 – 2019

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1. Introduction:

Rainfall is one of the most essential climatic indicators of climate change, The changes in rainfall in space and time would impact runoff, soil moisture, and groundwater reserves. The study of the climate change effects on water resource planning and management necessitates the analysis of precipitation changes (Khayyat, et. al, p. 35, 2019; M. Nawaz, et. al., 2020, p.2).

The availability of long-term and temporally consistent rainfall time series is one of the most important criteria for undertaking a detailed study of regional and temporal variation and trends in rainfall in any location.

Agriculture activities, flood disaster risk management and reduction, drought, water harvesting, water supply to communities, and other human activities related to the spatiotemporal distribution of rainfall in any region benefit from the analysis of long-term climate time-series data at a high temporal and spatial resolution.

Water resource management, agricultural productivity, and climate change mitigation benefit from understanding the spatial distribution of rainfall and its temporal trends (Morales-Acuña, et al., 2021, p. 1).

Rainfall data and measurements from traditional ground weather stations have traditionally been the major sources of such climate data; however, due to limited or nonexistent station networks in many regions of the world, historical records from station observations are insufficient. As a result, satellite-based rainfall data are increasingly being utilized to supplement or replace station observations.

Even though long and temporally consistent rainfall time series is essential in climate analyses and applications, many countries' weather stations are not distributed in an optimal way to allow researchers to conduct deep and multidimensional analyses for different climate elements to support human activities, planning, and decisions.

As a result, there should be an alternative to fill this data gap and conduct advanced deep climatic analysis in the areas mentioned above. One of the best available alternatives is the CHIRPS (Rainfall Estimates from Rain Gauge and Satellite Observations) data with a spatial resolution of 4.5 * 5.5 km to fill this gap in the required data for the analysis.

CHIRPS (Climate Hazards Group Infrared Precipitation with Station Data) is a rainfall dataset that combines 0.05° resolution satellite imaging with in-situ station data to produce gridded rainfall time series for trend analysis and seasonal drought monitoring. CHIRPS also employs sophisticated interpolation algorithms and high resolution (0.05°) rainfall predictions based on infrared Cold Cloud Duration (CCD) data over a long period (Funk et al., 2015; Shami, S., 2019)

2. Study Area:

The study area Dashti Hawler District (DHD) is in the middle–southern part of Erbil province, the Kurdistan Region of Iraq. It’s situated between longitudes ~43.87102°E - 44.32174°E and latitudes ~36.33076°N - 35.77226°N.

The DHD extends over an area of ~130,750 Hectares, which constitutes (~8.8 %) of the total area of Erbil Governorate. It is a flat area with a low slope in its central parts and is more rippled in the western, northern, and northeastern parts. DHD forms a relatively broad flat area in the form of a basin in which it has gathered and to a great depth, clay, sand, and gravel deposits interspersed with some shallow valleys that drain its water into the Great Zab and Little Zab stream.

The study area is bordered by the heights of Bestana, Sharabot in the north and east, the little Zab River in the south-east and the administrative boundaries of the districts of Erbil centre, Khabat in the west, and Avana mountain from the south (Ahmed, Rozhan, 2012, p.26; Kahraman, Layla Mhamad, 2004, pp. 19 - 31; Ismaeel, Sulaiman A., 2017, pp. 1 - 2).

The elevation of the study area ranges from 250m in its southern parts to more than 1,000m in its northern parts (Figures 1-A, B, C & Figure2).

The rainfall of the study area follows the Mediterranean system, which is characterized by its winter and spring rains caused by Mediterranean hurricanes and weather depressions passing through it the summer is dry, the temperature decreases in winter and rises in summer in all parts of the study area, the average of annual temperature in the study area is 22^{o}, and the average temperature of winter is 10^{o}, while the average temperature of Summer is 34.11^{o} (KRG, MoT&C)

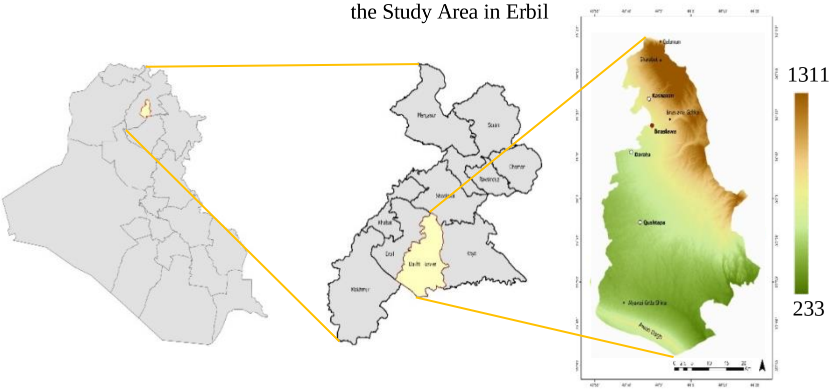
According to the Koppen classification, the study area is classified under the Semi-Arid climate zone (BSh) (Hassan, Tarq khidr, 2006, pp. 141 - 143)

Figures 1, A, B, C – Study Area

Figure 1-A: The location of the

Figure 1-B: The location of the Study Area in Erbil

Figure 1-C: Topography of



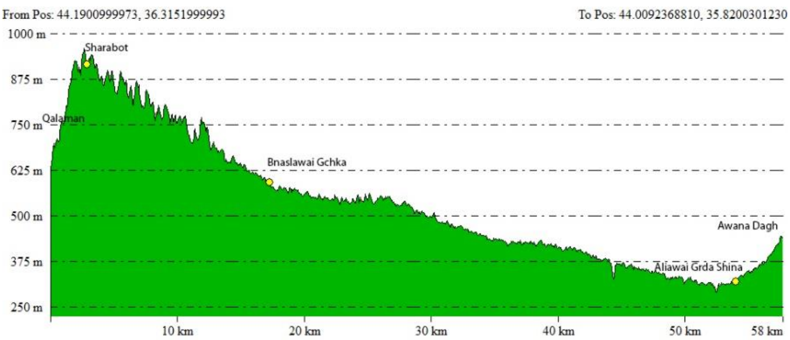


Figure 02: The Topographic Profile of the Study Area

3. **Research Problem and Objective:**

The Kurdistan Region of Iraq is experiencing a large-scale semi-aridization of the climate, especially noting a change in the characteristics of the rains, as evidenced by rising temperatures and decreasing precipitation, with detrimental consequences such as desiccation of vegetative cover and surface water (Khayyat H.A.K.A., et al, 2020, p. 463).

The problem of the study area is that there is a change in the characteristics of the rainfall of the Kurdistan Region of Iraq (KRI), including the study area, in terms of the amount of rainfall during the rainy season, which extends from the beginning of September until the end of May, the average of its monthly and daily sums, the beginning and end of each season, the dry periods and their length within the rainy season in the study area (Ismaeel, Sulaiman, 2010, pp. 77 – 78).

The importance of conducting the current study and analysis for Dashti Hawler district rainfall using the CHIRPS dataset for 40 years is that there is no weather station available in the study area with deep historical data to measure different climate elements.

The only weather station available in the study area is the weather station belonging to the Ministry of Agriculture (44.1178465°E, 36.1566008°N) and the data of this station is available since 2000, but in an interrupted way which the data of several years and months in between are missing, then the other closest weather station with long historical data is Erbil city weather station (44.0638808°E, 36.1974764°N).

However, the data of Erbil station does not include the data of the DHD that it is Dashti Hawler district because it's far more than 45 Kms from the southern parts of the study area. The topography of the majority of the study area is different from than Erbil weather station (which is based inside Erbil City), and also considering the lack of detailed climatic data on the monthly temperature and rainfall rate for historical periods, due to the political situation experienced by the region over the last three decades(Khayyat H.A.K.A., 2020), and the other closest weather station is Qushtapa station (which is relatively a new station and doesn't have deep historical data), that's why the current study aimed to draw a picture of the reality of 40 years of rainfall variability using the CHIRPS historical rainfall data in the study area for climate change assessments and rainfall trends.

The high 0.05°x0.05° spatial resolution of CHIRPS computations is designed to capture more reflective features of precipitation. Furthermore, CHIRPS data includes precipitation time series from 1981 to the present, enabling long-term hydrological research and simulation (Awchi, Taymoor, et al. 2021; Tuo Y, et al., 2016).

4. **<u>Research Methodology:</u>**

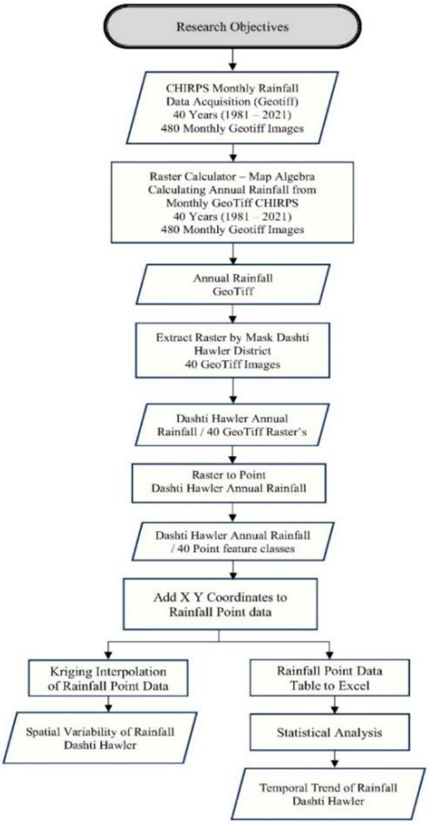
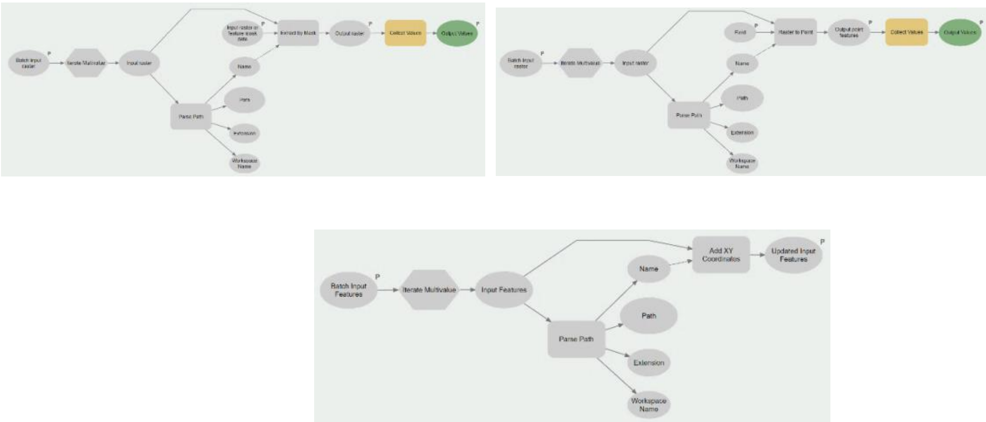


Figure (3) Research Methodology flowchart.



Figures (4, 5, 6) Data extraction – analysis flow model

5. <u>Data Analysis:</u>

Satellite rainfall products, such as the Climate Hazards Group InfraRed Precipitation with Stations (CHIRPS) product, have become a viable alternative to rain gauge stations in areas where rain gauges are scarce (Franklin Paredes-Trejo, et al., 2020, pp. 1 - 2).

CHIRPS (Climate Hazards Group InfraRed Precipitation with Station Data) is a quasi-global rainfall data set. As the name implies, it estimates precipitation by combining data from real-time observing meteorological stations with infrared data. The data spans the years 1981 through the present.

Due to the lack of well-distributed meteorological stations, satellite-based monthly rainfall data with a spatial resolution of 0.05 degrees obtained from the CHIRPS data is one of the best solutions available for researchers. (Attafi, R, et al. 2021).

For trend analysis and seasonal drought monitoring, CHIRPS builds gridded rainfall time series using 0.05° resolution satellite imagery and in-situ station data. With funding from the US Agency for International Development (USAID), the National Aeronautics and Space Administration (NASA), and the National Oceanic and Atmospheric Administration (NOAA), USGS and CHG scientists have been developing techniques for producing rainfall maps, especially where surface data is sparse since 1999 (https://www.waters.com/CHIRPS/).

CHIRPS data with 1-month temporal resolution and 5km geographical resolution is available at the UCSB Climate Hazard Group (CHG) website (https://www.chc.ucsb.edu/data/chirps). The presented monthly CHIRPS data was acquired to examine the Spatio-temporal variability of annual rainfall seasons (beginning on September 1st and ending on May 31st) for 40 rainfall seasons (1982 – 2021). The presented monthly CHIRPS data was acquired to examine the Spatio-temporal variability of annual rainfall seasons (beginning on September 1st and ending on May 31st) for 40 rainfall seasons (1982 – 2021). (P. Sandeep, et al., 2020, pp. 1 - 2).

As shown in the research flow chart (figure 3), 480 Geo tiff images of the monthly CHIRPS rainfall have been downloaded and then processed through the Raster Calculator – Map Algebra tool which was used in ArcGIS Pro. to extract the annual rainfall of 40 years, then the extracted annual rainfall has been masked with the polygon of Dashti Hawler district to extract the CHIRPS rainfall raster cells of the study area, which resulted in 40 Geo tiff rasters of the targeted area.

Then the Geo tiff raster of the annual rainfall of the Erbil area has been converted to points using the raster to point tool in ArcGIS Pro, then the X Y coordinates were added to the 40 point shapefiles of annual rainfall to prepare them for further interpolation process of the spatial distribution of rainfall over the study area using Kriging interpolation method.

The 40 annual rainfall feature classes were converted to Excel using the point to Excel tool in ArcGIS Pro To prepare them for further statistical analysis to detect the trends and characteristics of the 40 years of annual rainfall in Dashti Hawler district, then the outcomes were 40 maps of spatial distribution and spatial variation of rainfall in the study area, and several statistical tables and figures explaining the trends and characteristics of the 40 years annual rainfall in the study area.

5.1.Results and Discussions:

For the rainfall trends and statistical analysis, the annual rainfall over the study area has been extracted by counting the averages of the rainfall of all the 49 CHIRPS points (Figure 7) of each year inside the study area.

Then those annual averages were used for the statistical analysis and assessing the trends and other characteristics of rainfall over the years in the study area.

While for the spatial variation of rainfall over the study area, for each year, all the 49 CHIRPS points data were used to be integrated into the spatial interpolation of the rainfall using the Kriging interpolation method to prepare the map of the spatial distribution of rainfall over the study area for the targeted 40 years period, then as a result, 40 maps of the spatial distribution of rainfall were prepared using ArcGIS Pro.

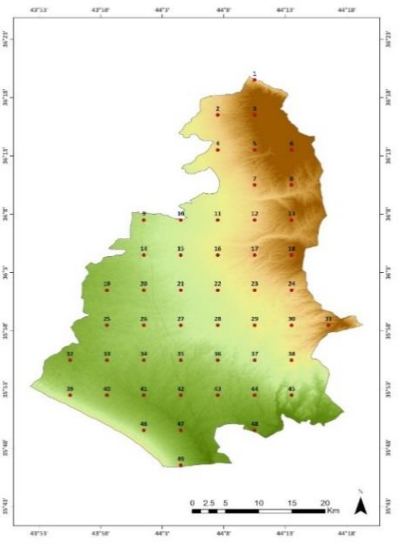


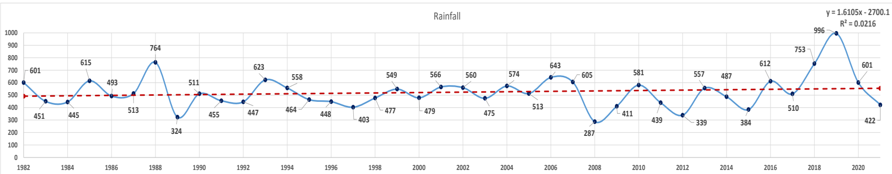
Figure 07: Distribution of CHIRPS 49 points over the study area (Dashti Hawler District)

5.2.<u>Statistical Analysis:</u>

5.2.1. Average Rainfall in Study Area:

The statistics of the processed rainfall data from CHIRPS rasters show that there is a big variation in rainfall amount in the study area over the study period, which the maximum rainfall amount was recorded in the rainfall season 2018 – 2019 (996 mm) while the driest season was in the rainfall season 2007 – 2008 which only an amount of (287 mm) of rainfall was received in the study area, which means a variance of (709 mm) of rainfall between the minimum and maximum annual rainfall amount; moreover, the average rainfall of the study area for the 40 years of the study period was 523 mm of rainfall with a relatively high standard deviation of the annual rainfall which is 128, this high value of the STDV is indicating to the statistical fact that the rainfall in the study area is characterized by its high variation over years and the fluctuation in annual rainfall is the dominant characteristic of the rainfall in the study area. That’s why this annual average doesn’t show the real picture of rainfall in the study area (figure 8 & table 1).

Figure 8: Rainfall trend in Dashti Hawler 1982 - 2021



Regarding the trend of annual rainfall compared to the 40 years average rainfall in the study area, the statistics show that from the rainfall of the 40 years of the study period, only 17 years recorded a positive rainfall value compared to the average of the study area, while the rainfall of 23 years recorded a negative rainfall trend compared to the 40 years average rainfall in the study area.

Although the statistics show that 17 years recorded positive rainfall amount (annual rainfall was above the 40-year average) and 23 years recorded negative amount of rainfall (annual rainfall was below the 40 years average) compared to the 40 years average but comparing the yield rainfall from each group of years (positive and negative rainfall compared to average) shows that the yielded rainfall during the years which their rainfall was above the average was (10756 mm) vs (10177 mm) during the years which their rainfall average was below average,

This means that from the total (20933 mm) rainfall over the study area during the 40 years of the study period, (10756 mm) 51 % of the received rainfall was during the 17 years which is more than received rainfall during the negative 23 years (10177 mm) 49%, and this fact proves what has mentioned above that the rainfall in the study area is characterized by its high variation over years and the fluctuation in annual rainfall is the dominant characteristic of the rainfall in the study area.

Table 1: Rainfall statistics in Dashti Hawler 1982 - 2021

Year	Rainfall mm	Change %	The difference in Average mm	5 Years Moving Average
1982 – 2021 - Average	523			
1982	601	15	78	
1983	451	-14	-72	
1984	445	-15	-78	521
1985	615	18	92	503
1986	493	-6	-30	566
1987	513	-2	-10	542
1988	764	46	241	521
1989	324	-38	-199	513
1990	511	-2	-12	500
1991	455	-13	-68	472

Year	Rainfall mm	Change %	The difference in Average mm	5 Years Moving Average
1992	447	-15	-76	519
1993	623	19	100	509
1994	558	7	35	508
1995	464	-11	-59	499
1996	448	-14	-75	470
1997	403	-23	-120	468
1998	477	-9	-46	471
1999	549	5	26	495
2000	479	-8	-44	526
2001	566	8	43	526
2002	560	7	37	531
2003	475	-9	-48	538
2004	574	10	51	553
2005	513	-2	-10	562
2006	643	23	120	524
2007	605	16	82	492
2008	287	-45	-236	505
2009	411	-21	-112	465
2010	581	11	58	411
2011	439	-16	-84	465
2012	339	-35	-184	481
2013	557	6	34	441
2014	487	-7	-36	476
2015	384	-26	-139	510
2016	612	17	89	549
2017	510	-2	-13	651
2018	753	44	230	694

Year	Rainfall mm	Change %	The difference in Average mm	5 Years Moving Average
2019	996	90	473	656
2020	601	15	78	
2021	422	-19	-101	
Total	20933			
Min	287	-45	-236	411
Max	996	90	473	694
Average	523	0.06	0.3	518
STDV	128	24	128	56. 9
Rainfall mm_Above Average	10756	17 Years	51%	
Rainfall mm_Below Average	10177	23 Years	49%	

It can be noticed from Table 1 above that from the top 10 abundant rainfall years, 4 records are in the 4th quarter (2012 – 2021) of the study period and 3 records are in the 1st quarter (1982 – 1991), and 2 records are in the 3rd quarter (2002 – 2011) and only 1 out of top 10 records is in the 2nd quarter (1992 – 2001).

From the same table (1), it can be noticed that from the top 10 scarce rainfall years, 3 records are in each one of the 3rd and 4th quarters, and each one of the 1st and 2nd quarters has only 2 records. it's worth mentioning that the 4th quarter is the less stable period in the study area because 4 out of the top 10 abundant rainfall years are in this quarter, but also 3 out of the top 10 scarce rainfall years are in this quarter, and this fluctuated numbers affected the overall trend of rainfall in the study area.

Five years moving Average Rainfall in Study Area:

This method is one of the most statistical methods used by climatologists to study the nature of different climate variability to reduce irregular fluctuations and thus show regular rain fluctuations in the study area (Khairallah, Hafidh Issa, 2019). A moving average is widely used to smooth out short-term variations while highlighting longer-term patterns or cycles when dealing with time-series data. The short-term vs. long-term threshold is determined by the application, and the moving average parameters are adjusted accordingly (www.wikipedia.org).

Table 1 and figure 9 show the five years moving average of annual rainfall in the study area. It is obvious from the table that the minimum average of annual rainfall using the five years moving average is (411 mm) of rainfall in five years moving average of rainfall of 2011. While the minimum annual average for the real rainfall calculated from the same table was only (287 mm), this is due to the normalization of values after applying the five years moving average function. In addition, the maximum average of annual rainfall using the five years moving average method was (694 mm) of rainfall in the five years moving average of rainfall of 2018, which varies from the real annual rainfall calculated from the same table (996 mm).

The figures above clearly show the high range (709 mm) between the minimum (287 mm) and maximum (996 mm) of the actual annual rainfall values, and the lower range (283 mm) between the minimum (411 mm) and maximum (694 mm) of the calculated five years moving average rainfall values calculated through the 5 years moving average.

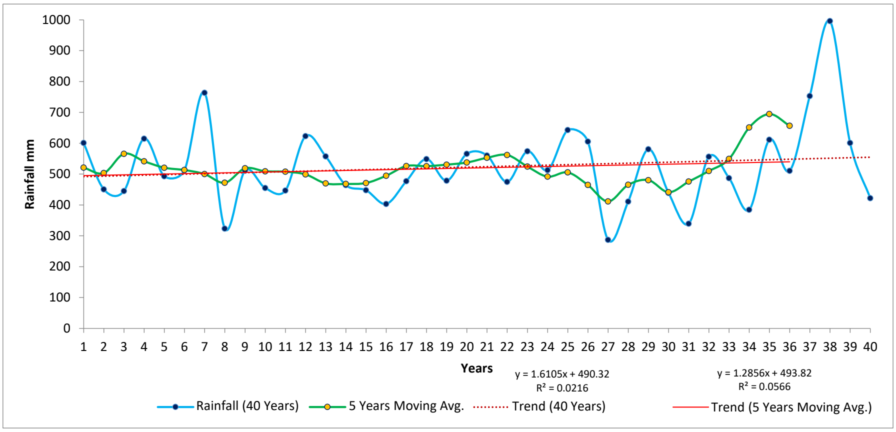


Figure 9: Five years moving average of annual rainfall in the study area vs the 40 years rainfall graph

5.3. Rainfall Trends:

As shown in table (2) below and figure (8) above, although out of the 40 years of the periodical coverage of the study, 23 years of rainfall were recorded below the general average of the study area.

Although only the rainfall of 17 years was recorded above the general average of the study area, still the general overall rainfall status in the study area for the covered period is showing that the start point of the trend line is (491.9 mm) and the endpoint of the trend line is (554.7 mm) which indicates to a positive direction in the linear trend (+62.8) with a high standard deviation value (128) for the rainfalls of the 40 years, which refers to the high fluctuation and variation between the rainfall amounts among the years of the study period.

This positive direction in the 40 years rainfall trend line in the study area is supported by the calculations of the rainfall trend using the 5 years moving average method, in which the start point of the trend line is (495.1 mm) and the endpoint is (540.1 mm), and this again referring to a positive trend in rainfall of the study area with a trend value (45) and a relatively lower standard deviation value (56.9) compared to the 40 years rainfall values, and this is due to applying the moving average method which has normalized the rainfall values and reduced the big variation among the rainfall values, but still, the trend is showing a positive direction but relatively lower than the trend of the 40 years rainfall.

Diving more deeply into the rainfall data of the study area, and considering dividing the studied period (40) years into 4 equal quarters of (10 Years), to discover more about the characteristics of rainfall in the study area and the precise responsibility factors affecting the overall trend of rainfall in the study area, shows that the first quarter (1982 – 1991) and third quarter (2002 – 2011) both are showing negative trends of rainfall in the study area.

The average rainfall in the first quarter is (517 mm) which is the closest average to the overall average of rainfall during the 40 years of the study period, with a negative trend value of (-56.3) for the first quarter (1982 – 1991) and the value of R^2 is (0.03) and the standard deviation is 120, the numbers are indicating to a slight negative trend in the annual rainfall values which the low value of the R2 is indicating to this fact, with a high variation of the annual rainfall of different years which the high value of the standard deviation is indicating to this fact.

The rainfall average received during the third quarter (2002 – 2011) was (501 mm), and the rainfall amounts received during the third quarter are showing a relatively higher negative trend in the rainfall over the study area (-102.4), which the trend line starts at the point (560 mm) and ends at the point (457.6 mm) with a relatively higher R^2 value (0.1) to confirm the negative trend line, and a lower standard deviation value (108) compared to the first quarter, which indicates to less variation in the annual rainfalls around the average of the 3rd quarter.

From the rainfall values and the statistical analysis, it has been indicated that the second quarter is the most stable quarter among the 4 quarters in the study area with an average rainfall (501 mm) and the less standard deviation value (69) among all the 4 quarters, which indicates to the less variation of the received annual rainfall amounts around the average rainfall of the 2nd quarter, the result of the above facts is that there is no presence of a significant trend (either negative or positive) of the rainfall in the second quarter, which the trend value is only (0.8) with an R^2 value (0.00002).

The Fourth quarter of the period (2012 – 2021) characterized by an average rainfall (566 mm) (which is the highest among all the quarters), is the only quarter that recorded a relatively high positive trend of rainfall in the study area with a positive trend value (251.1) which indicates to a high positive trend in rainfall of the study area and the high R^2 (0.19) value compared to other quarters, supports this fact of the high positive trend.

Moreover, one notable characteristic of the rainfall in the 4^{th} quarter is its high standard deviation value (194) which is also the highest among all the quarters, this high standard deviation value indicates the big variation in rainfall values among the 10 years of the 4^{th} quarter, this is because out of 10 highest recorded rainy years (2016, 2018, 2019 and 2020) are in the 4^{th} quarter, but also 3 out of the 10 less lowest recorded rainy years (2012, 2015 and 2021) are in the 4^{th} quarter.

However, these two facts mentioned above caused the big variation in the received rainfall amounts among the 10 years of the 4^{th} quarter, which is verified by the big value of the standard deviation of the 4^{th} quarter (194) which is the highest among the 4 quarters.

Additionally, the high received rainfall values of the 4^{th} quarter have a big impact on the overall average rainfall of the 40 years in the study area, as well as impacted the overall trend of rainfall in the study area (which was explained previously), especially the two years 2018 with (753 mm) rainfall and 2019 with (996 mm) rainfall, which recorded the highest received rainfall in the study area over the 4 decades of the study period.

These extreme high values affected statistically all the other figures and numbers in the study area, in such a way that the values of the received rainfall in those two years (2018 & 2019) were around the average rainfall in the study area (523 mm), then the rainfall trend was showing a negative trend over the 40 years in the study area, and this is the significance of conducting more deep statistical analysis on different parts of the data to detect and assess the extreme values which are affecting the statistical results of any periodical data.

Table 2: Rainfall trend directions, values in Dashti Hawler (40 years annual, 5 years moving average, 10 years quarterly)

Period		Average Rainfall	STDV	Change Direction (Trend)			R2
				Trendline Start (mm)	Trendline End (mm)	Trend Direction / Value	
40 Years 1982 – 2021		523	128.0	491.9	554.7	62.8	0.02160
5 Years Moving Average		518	56.9	495.1	540.1	45.0	0.05660
10 Years Quarterly Average	Q1 - 1982 – 1991	517	120.0	545.3	489.0	-56.3	0.03000
	Q2 - 1992 – 2001	501	69.0	500.9	501.7	0.8	0.00002
	Q3 - 2002 – 2011	509	108.0	560.0	457.6	-102.4	0.10000
	Q4 - 2012 – 2021	566	194.0	440.6	691.7	251.1	0.19000

5.4.Kriging Interpolation of Spatial Rainfall Variability:

Many applications in hydrology and agriculture rely on precipitation data; However, no matter how dense a region's network of measurement stations is, there will always be many sites where precipitation data is unavailable.

As a result, measurements from nearby sites must be used to estimate point rainfall at unrecorded locations (M. Coulibaly, et al, 2007, p 494; Goovaerts, 1999).

In the current study, the mean annual rainfall has been calculated from the CHIRPS monthly raster data using the map algebra raster calculator tool in ArcGIS Pro, and then the generated rasters of the annual rainfall have been converted to points over the study area which resulted in containing 49 CHIRPS points of annual rainfall in the study area.

Then to generate the Isohyet map of mean annual rainfall the Kriging/CoKriging - Ordinary Kriging – Prediction method has been used to estimate the rainfall values in the areas between the generated 49 CHIRPS points over the study area. The ordinary kriging interpolation method can be used with satisfactory performance in interpolating the annual rainfall data (Wilmar L. Cerón, et al, 2021, pp. 6 - 7).

The results of the Kriging interpolation are presented in the isohyet map of mean Annual Rainfall (mm) in the study area for the 40 years of the study period (1982 – 2021). Figure (13) shows the spatial variability of rainfall among different parts of the study area.

Based on the used CHIRPS data, the geographic distribution of rainfall in the study area can be characterized by its spatial distribution of rainfall amounts which vary between the North and North-East parts of the study area, which received the maximum rainfall amounts in all the years. Moreover, the amount of rainfall decreases by moving downward the study area to the South and South-West parts, which received the minimum rainfall amounts in all the years.

The minimum rainfall isohyet area identified on the maps is 300 mm rainfall which includes areas that received rainfall less than 300 mm at that year, and this was presented in three rainfall years only (1989, 2008, 2012). These three years (2008, 1989, and 2012) can be considered the most scarce rainfall years in the study area respectively. The maps are indicating that this scarcity rainfall area is expanding to its maximum area occupation in the study area in 2008 (which from the mean rainfall amounts was the most scarcity rainfall year) and covers the middle and western and southern parts of the study area, while in 2012 this rainfall scarcity area shrinks to its minimum and occupied a very small area in the far southern part of the study area.

The maximum rainfall isohyet area observed in the study area on the maps is 1400 mm, which included the areas that received rainfall between 1300 – 1400 mm. This area was observed only in one rainfall year (2019) and the amounts of rainfall reached the peak which never happened during the study period. This high rainfall area on the map occupied the North-Eastern part of the study area which is on all the maps the highest and the most abundant rainfall area among the other parts of the study area.

It’s worth mentioning that from the spatial distribution of rainfall over the study area that the second and third highest abundance rainfall isohyet areas were also observed only in the abundance rainfall year 2019 which occupied the North and North-Eastern parts of the study area to the south of the 1400mm rainfall isohyet area.

The figure (10) below shows the frequency of occurrence of each rainfall isohyet area among the 40 years of the temporal coverage of the study, and it can be indicated that the rainfall isohyet area with 600 mm (areas with rainfall between 500 – 600 mm) is the most repeated (34 years) among all the other rainfall isohyet areas, and this is reflecting the fact of the average of the 40 years which was 523 mm of rainfall.

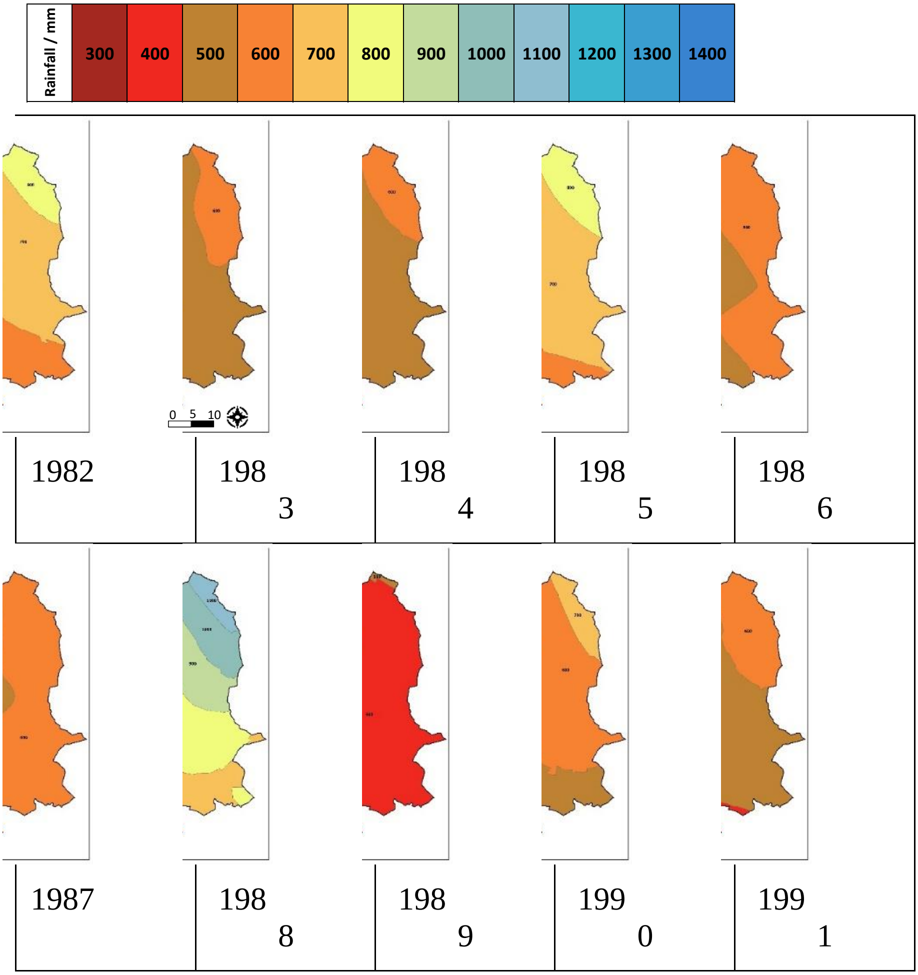
After the 600 mm rainfall isohyet area, the most repeated isohyet areas in the study area were (500 mm \ 31 years), (700 mm \ 25 years), (400 & 800 mm \ 15 years), (500 mm \ 5 years), (300 & 1000 mm \ 3 years), (1100 mm \ 2 years), (1200, 1300, 1400 mm \ 1 year only) respectively.

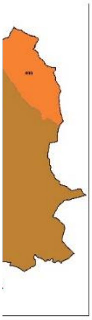
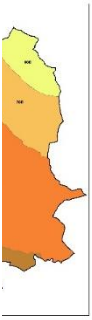
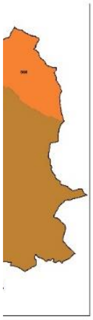
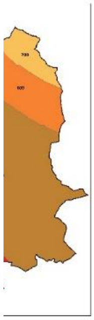
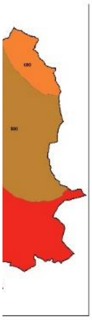
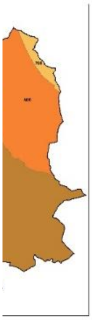
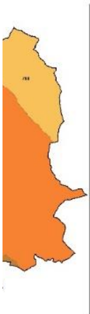
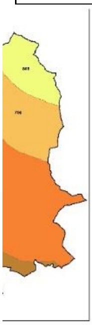
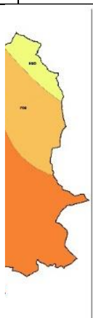
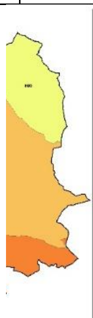
Scrutinizing the 40 maps of the spatial distribution of rainfall over the study area leads to the fact that the rainfall isohyet areas of the same value vary among the years in which the rainfall isohyet areas are repeated, and their coverage areas vary among the years, this kind of analysis is of big value and importance for different kind of activities and planning for agricultural activities and water harvesting.

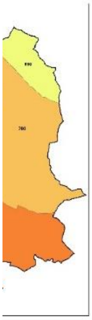
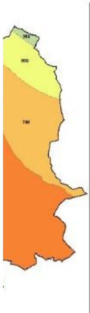
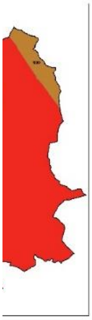
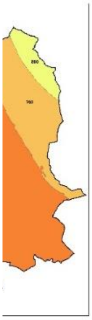
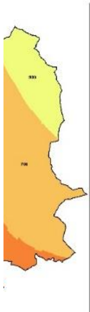
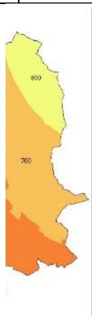
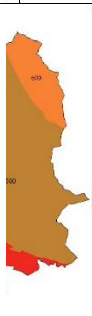
Rainfall / mm	300	400	500	600	700	800	900	1000	1100	1200	1300	1400
Years	1989	1983	1983	1982	1982	1982	1988	1988	1988	2019	2019	2019
	2008	1984	1984	1983	1985	1985	1993	2018	2019	**1**	**1**	**1**
	2012	1989	1986	1984	1988	1988	2010	2019	**2**			
	3	1991	1987	1985	1990	1993	2018	**3**				
		1992	1989	1986	1993	1994	2019					
		1995	1990	1987	1994	2002	**5**					
		1996	1991	1988	1996	2004						
		1997	1992	1990	1998	2006						
		2008	1993	1991	1999	2007						
		2009	1994	1992	2000	2010						
		2011	1995	1993	2001	2013						
		2012	1996	1994	2002	2016						
		2014	1997	1995	2003	2018						
		2015	1998	1996	2004	2019						
		2021	1999	1997	2005	2020						
		15	2000	1998	2006	**15**						
			2001	1999	2007							
			2002	2000	2010							
			2003	2001	2011							
			2004	2002	2013							
			2005	2003	2014							
			2009	2004	2016							
			2010	2005	2017							
			2011	2006	2018							
			2012	2007	2020							
			2013	2009	**25**							
			2014	2010								
			2015	2011								
			2017	2013								
			2020	2014								
			2021	2016								
			31	2017								
				2020								
				2021								
				34								

Figure (10): The frequency of occurrence of each rainfall isohyet area

Figure (11): Spatial variation of the mean annual rainfall distribution in Dashti Hawler district 1982 – 2021 based on CHIRPS database and Kriging interpolation



				
1992	199 3	199 4	199 5	199 6
				
1997	199 8	199 9	200 0	200 1
				
2002	200 3	200 4	200 5	200 6

				
2007	2008	2009	2010	2011
				
2012	2013	2014	2015	2016
				
2017	2018	2019	2020	2021

6. Conclusion:

The current research aimed to evaluate the potential of the CHIRPS rainfall dataset and Kriging interpolation with statistical analysis for analyzing the Spatio-temporal trends of rainfall in Dashti Hawler District – Erbil Governorate, Kurdistan Region of Iraq.

The CHIRPS rainfall dataset was a useful alternative to the ground weather stations which the study area with its area of ~130,750 Hectare has only one weather station (Bnaslawa station) with poor historical data, even the available data is an incomplete dataset, which has interruption years and months due to several local and technical reasons.

Furthermore, the CHIRPS dataset with its flexible structure and format provides the opportunity for many different spatial analyses with raster or vector data and the possibility of performing different statistical analyses from the dataset.

Conjointly with the CHIRPS dataset, the researcher can provide very accurate and precise results from his analysis to support the decision-makers to take the correct and quick decision on any related issues or topics.

One of the important and powerful positive points of using the CHIRPS rainfall dataset is that it allows the researcher to perform the analysis on different temporal levels (Monthly, Seasonal, Annual) and observe the structure of the data to detect the fluctuations and trends in the data and measuring the significance of the results.

The results of CHIRPS datasets can be integrated into different studies of environmental, climatical, agricultural, hydrological,…etc. models further deep analysis on drought monitoring, agricultural production planning, hydrological studies, climate change aspects, and features, climatical classification systems, and their transitions and changes spatiotemporally.

The results of the study show a wide fluctuation in the received rainfall amounts in the study area over the 40 years of the study period, this fluctuation is in such a way that the extremely high rainfall values of some years, for example: (1988 = 764 mm), (2018 = 753 mm), (2019 = 996 mm) statistically affected the overall trend of rainfall in the study area and hid extreme dry rainfall years.

That caused the general overall rainfall status in the study area for the covered period is showing a positive direction in the linear trend (+62.8) with a high standard deviation value (128) for the rainfalls of the 40 years, which refers to the high fluctuation and variation between the rainfall amounts among the years of the study period.

Regarding the spatial variation of rainfall in the study area over the 40 years of the study period, the CHIRPS dataset through the geostatistical analysis tools and methods made it possible to estimate the amount of rainfall in the whole study area using Kriging interpolation, and this resulted in to have a detailed map of precipitation in the study area with isohyets dividing the study area into rainfall areas with an interval of 100 mm between the spatial distributions of rainfall areas.

By using the Kriging interpolation for the converted CHIRPS raster datasets into points, it was possible to estimate the rainfall values in the areas between the generated 49 CHIRPS points over the study area and to monitor the most repeated rainfall isohyets over the study period and indicated to that the rainfall isohyet area with 600 mm (areas with rainfall between 500 – 600 mm) is the most repeated (34 years) among all the other rainfall isohyet areas, and this is reflecting the fact of the average of the 40 years which was 523 mm of rainfall.

Whereas the rainfall isohyets 1200, 1300, 1400) were visible in only 1 year (2019 – the top abundance year in the study area), and isohyet (1100) was visible in only 2 years, and (1000) in only three years, but those extreme high rainfall values statistically affected the overall trend of rainfall to direct it into a positive direction.

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پوختە

ئامانجی ئەم توێژینەوەیە بریتیە لە هەڵسەنگاندنی توانای داتا سێتی بارانبارینی CHIRPS و ئینتەرپۆلەیشنی کریگینگ لەگەڵ شیکاری ئاماری بۆ شیکردنەوەی ڕەوتی شوێنی - کاتی بارانبارین لە قەزای دەشتی هەولێر – پارێزگای هەولێر، هەرێمی کوردستانی عێراق .

داتا سێتی بارانبارینی CHIRPS جێگرەوەیەکی بەسوود بوو بۆ وێستگەکانی کەشوهەوای زەوی کە ناوچەی توێژینەوەکە بە ڕووبەرەکەی ~١٣٠,٧٥٠ هێکتار تەنها یەک وێستگەی کەشوهەوای هەیە)وێستگەی (Bnaslawa لەگەڵ داتا مێژووییە ناتەواوەکەی، تەنانەت داتا بەردەستەکان داتایەکی ناتەواون، کە ساڵانی پچڕانی هەیە بەهۆی چەند هۆکارێکی ناوخۆیی و تەکنیکیەوە .

سەرەڕای ئەوە، کۆمەڵە داتاکانی CHIRPS بە پێکهاتە و فۆرماتە گونجاوەکەیەوە دەرفەت دەڕەخسێنێت بۆ چەندین شیکاری شوێنی جیاواز بە داتاکانی ڕاستەر یان ڤێکتەر و ئەگەری ئەنجامدانی شیکاری ئاماری جیاواز لە کۆمەڵە داتاکانەوە. بە هاوبەشی لەگەڵ کۆمەڵە داتاکانی CHIRPS، توێژەر دەتوانێت ئەنجامێکی زۆر ورد لە شیکارییەکانییەوە پێشکەش بکات بۆ پشتگیریکردنی بڕیاردەران بۆ بڕیاردانی دروست و خێرا لەسەر هەر پرسێک یان بابەتێکی پەیوەندیدار .

یەکێک لە خاڵە ئەرێنییە گرنگ و بەهێزەکانی بەکارهێنانی داتا سێتی بارانبارینی CHIRPS ئەوەیە کە ڕێگە بە توێژەر دەدات شیکارییەکە لەسەر ئاستە کاتییە جیاوازەکان (مانگانە، وەرزی، ساڵانە) ئەنجام بدات و چاودێری پێکهاتەی داتاکان بکات بۆ دیاریکردنی هەڵاوسان و ڕەوتەکان لە داتا و پێوانەکردنی گرنگی ئەنجامەکان .

دەتوانرێت ئەنجامەکانی کۆمەڵە داتاکانی CHIRPS لە توێژینەوە جیاوازەکانی ژینگە، کەشوهەوا، کشتوکاڵی، هایدرۆلۆجی،...هتد یەکبخرێن. مۆدێلی شیکاری قووڵی زیاتر لەسەر چاودێریکردنی وشکەساڵی، پلاندانانی بەرهەمی کشتوکاڵی، توێژینەوەکانی ئاو، لایەنەکانی گۆڕانی کەشوهەوا، و تایبەتمەندییەکان، سیستەمی پۆلێنکردنی کەشوهەوا، و گواستنەوە و گۆڕانکارییەکانیان لە ڕووی فەزایی و کاتییەوە دەکات .

ئەنجامەکانی توێژینەوەکە هەڵاوسانێکی بەرفراوان لە بڕی بارانبارینی وەرگیراو لە ناوچەی توێژینەوەکە نیشان دەدات لە ماوەی ٤٠ ساڵی ماوەی توێژینەوەکەدا، ئەم هەڵاوسانە بە جۆرێکە کە بەهای بارانبارینی زۆر بەرزی هەندێک ساڵ، بۆ نموونە: (١٩٨٨ = ٧٦٤ ملم)، (٢٠١٨ = ٧٥٣ ملم)، (٢٠١٩ = ٩٩٦ ملم) لە ڕووی ئامارییەوە کاریگەرییان لەسەر ڕەوتی گشتی بارانبارین لە ناوچەی توێژینەوەکە هەبوو و ساڵانی بارانبارینی و وشکەساڵی زۆریان شاردەوە .کە بووە هۆی ئەوەی کە دۆخی گشتی بارانبارین لە ناوچەی توێژینەوەکە بۆ ماوەی توێژینەوەکە ئاراستەیەکی ئەرێنی لە ڕەوتی هێڵی (+٦٢.٨) نیشان دەدات لەگەڵ بەهای لادانێکی ستانداردی بەرز (١٢٨) بۆ بارانبارینی ٤٠ ساڵ، کە ئاماژەیە بۆ هەڵاوسانی بەرز و گۆڕانکاری لە نێوان بڕی بارانبارین لە نێوان ساڵانی ماوەی توێژینەوەکەدا .

سەبارەت بە گۆڕانی شوێنی بارانبارین لە ناوچەی توێژینەوەکە لە ماوەی ٤٠ ساڵی ماوەی توێژینەوەکەدا، کۆمەڵە داتاکانی CHIRPS لە ڕێگەی ئامراز و شێوازەکانی شیکاری جیۆئامارییەوە وایکرد کە بتوانرێت بڕی بارانبارین لە تەواوی ناوچەی توێژینەوەکەدا بە بەکارهێنانی شینتەرپۆلەیشنی کریگینگ بخەملێندرێت، و ئەمەش لە ئەنجامدا بووە بۆ ئەوەی نەخشەیەکی وردی بارانبارین لە ناوچەی لێکۆڵینەوەکەدا هەبێت لەگەڵ ئایزۆهیتەکان کە ناوچەی توێژینەوەکە دابەش دەکەن بەسەر ناوچە

باراناوییەکاندا بە ماوەی ١٠٠ ملم لە نێوان دابەشکردنی شوێنی ناوچە باراناوییەکان .

بە بەکارهێنانی ئینتەرپۆلەیشنی Kriging بۆ کۆمەڵە داتا ڕاستەری گۆڕدراوی CHIRPS بۆ خاڵ، توانرا بەهاکانی بارانبارین لە ناوچەکانی نێوان ٤٩ خاڵەکانی CHIRPS دروستکراو لەسەر ناوچەی توێژینەوەکە بخەملێندرێت و چاودێری زۆرترین دووبارەبوونەوەی ئایزۆهیتەکانی بارانبارین بکرێت لە ماوەی توێژینەوەکەدا و ئاماژەی پێکراوە بۆ کە ناوچەی ئایزۆهیتی بارانبارین بە ٦٠٠ ملم (ئەو ناوچانەی کە بارانبارینیان لە نێوان ٥٠٠ – ٦٠٠ ملیم دا هەیە) زۆرترین دووبارەبوونەوەیە (٣٤ ساڵ) لە نێوان هەموو ناوچە ئایزۆهێتەکانی تری بارانبارین، و ئەمەش ڕەنگدانەوەی ڕاستی تێکڕای ٤٠ ساڵەیە کە ٥٢٣ بووە ملم بارانبارین .لە کاتێکدا کە ئایزۆهیتەکانی بارانبارین ١٢٠٠، ١٣٠٠، ١٤٠٠) تەنها لە ١ ساڵدا دیار بوون (٢٠١٩ – ساڵی زۆرترین بڕی باران لە ناوچەی لێکۆڵینەوە)، و ئایزۆهیتی (١١٠٠) تەنها لە ٢ ساڵدا بینرا، و (١٠٠٠) تەنها لە سێ ساڵدا، بەڵام ئەو بەها زۆر بەرزانەی بارانبارین لە ڕووی ئامارییەوە کاریگەرییان لەسەر رەوتی گشتی بارانبارین هەبوو بۆ ئەوەی بەرەوە ئاراستەیەکی ئەرێنی ببات.

يهدف البحث الحالي إلى تقييم إمكانات مجموعة بيانات هطول الأمطار CHIRPSواستيفاء Kriging مع التحليل الإحصائي لتحليل الاتجاهات المكانية والزمانية لهطول الأمطار في منطقة دەشتي هەولير - محافظة أربيل، إقليم كوردستان العراق .

كانت مجموعة بيانات هطول الأمطار CHIRPS بديلاً مفيدًا لمحطات الطقس الأرضية، التي تحتوي منطقة الدراسة بمساحتها حوالي ١٣٠.٧٥٠ هكتارًا على محطة طقس واحدة فقط (محطة بنصلاوة) مع بيانات تاريخية غير متكامله، حتى البيانات المتاحة هي مجموعة بيانات ذات نقص كبير، والتي فيها انقطاع لسنوات وأشهر لأسباب محلية وفنية عديدة .

علاوة على ذلك، توفر مجموعة بيانات CHIRPS بهيكلها المرن وتنسيقها، الفرصة للعديد من التحليلات المكانية المختلفة باستخدام البيانات النقطية أو المتجهة وإمكانية إجراء تحليلات إحصائية مختلفة من مجموعة البيانات .

بالاشتراك مع مجموعة بياناتCHIRPS ، يمكن للباحث تقديم نتائج دقيقة للغاية من تحليله لدعم صانعي القرار لاتخاذ القرار الصحيح والسريع بشأن أية قضايا أو مواضيع ذات صلة .

تتمثل إحدى النقاط الإيجابية المهمة والقوية لاستخدام مجموعة بيانات CHIRPSفي أنها تتيح للباحث إجراء التحليل على مستويات زمنية مختلفة (شهرية، موسمية، سنوية) ومراقبة بنية البيانات لاكتشاف التقلبات والاتجاهات في البيانات وقياس أهمية النتائج . يمكن دمج نتائج مجموعات البيانات CHIRPSفي الدراسات المختلفة البيئية، والمناخية، والزراعية، والهيدرولوجية، ... إلخ نماذج مزيد من التحليل العميق لرصد الجفاف، وتخطيط الإنتاج الزراعي، والدراسات الهيدرولوجية، وجوانب تغير المناخ، وخصائصه، وأنظمة التصنيف المناخية، وتحولاتها وتغيراتها المكانية الزمانية .

أوضحت نتائج الدراسة وجود تذبذب كبير في كميات الأمطار الواردة في منطقة الدراسة على مدى ٤٠ سنة من فترة الدراسة، وهذا التذبذب يكون على نحو

يؤدي إلى ارتفاع شديد في قيم هطول الأمطار في بعض السنوات، على سبيل المثال: (١٩٨٨ = ٧٦٤ ملم)، (٢٠١٨ = ٧٥٣ ملم)، (٢٠١٩ = ٩٩٦ ملم) أثرت إحصائيًا على الاتجاه العام لهطول الأمطار في منطقة الدراسة وأخفت سنوات هطول الأمطار الشديدة الجفاف .

وقد تسبب ذلك في أن الحالة العامة لهطول الأمطار في منطقة الدراسة للفترة المشمولة تظهر اتجاهاً إيجابياً في الاتجاه الخطي (+٦٢.٨) مع قيمة انحراف معياري عالية (١٢٨) لسقوط الأمطار في الأربعين سنة، مما يشير إلى - تقلبات وتفاوتات عالية بين كميات الأمطار بين سنوات فترة الدراسة .

فيما يتعلق بالتباين المكاني لهطول الأمطار في منطقة الدراسة على مدار ٤٠ عامًا من فترة الدراسة، فإن مجموعة بيانات CHIRPS من خلال أدوات وطرق التحليل الإحصائي الجغرافي جعلت من الممكن تقدير كمية الأمطار في منطقة الدراسة بأكملها باستخدام الاستيفاءKriging ، وقد نتج عن ذلك الحصول على خريطة تفصيلية لهطول الأمطار في منطقة الدراسة مع تقسيم منطقة الدراسة إلى مناطق تساقط الأمطار بفاصل ١٠٠ مم بين التوزيعات المكانية لمناطق هطول الأمطار .

باستخدام الاستيفاء Kriging لمجموعات البيانات النقطية CHIRPS المحولة إلى نقاط، فقد تم تقدير قيم تساقط الأمطار في المناطق الواقعة بين نقاط CHIRPSالبالغ عددها ٤٩ نقطة فوق منطقة الدراسة ومراقبة أكثر تساوي تساقط الأمطار تكرارًا خلال فترة الدراسة والإشارة إلى أن تساقط الأمطار بمساحة ٦٠٠ مم (المناطق التي يتراوح معدل تساقط الأمطار فيها بين ٥٠٠ - ٦٠٠ مم) هي الأكثر تكرارًا (٣٤ عامًا) من بين جميع مناطق تساوي الأمطار الأخرى، وهذا يعكس حقيقة متوسط ٤٠ عامًا الذي كان ٥٢٣ مم من هطول الأمطار .في حين أن تساوي هطول الأمطار ١٢٠٠، ١٣٠٠، ١٤٠٠) قد ظهرت في عام واحد فقط (٢٠١٩ - عام الوفرة الأعلى في منطقة الدراسة)، isohyet ((1100 ظهرت في عامين فقط، و (١٠٠٠) في ثلاث سنوات فقط، لكن تلك القيم المتطرفة لسقوط الأمطار أثرت إحصائيًا على الاتجاه العام لهطول الأمطار لتوجيهه إلى اتجاه إيجابي.