Kirkuk University Journal for Agricultural Sciences
ISSN:2958-6585
https://kujas.uokirkuk.edu.iq

RESEARCH ARTICLE
https://doi.org. doi: 10.58928/ku24.15222

Assessment of Hydrological Drought Intensity and Frequency Using SPI in Sulaimanya Province, Iraq (2003-2022).

Alan Rahman Mustafa [1] **Dhahir Khaleel Ali [1]** **Dalshad Rasool Azeez [1]**
[1]*Department of soil sciences and water resources, College of Agricultural, Kirkuk University, Kirkuk, IRAQ.*
*Corresponding Author: aksm22002@uokirkuk.edu.iq.

Received: 14/04/2024 **Revised: 15/05/2024** **Accepted: 25/5/2024** **Published: 01/06/2024**

ABSTRACT

Drought is a recurring phenomenon, a natural feature of the climate, and one of the major natural hazards to which Iraq is repeatedly exposed, causing significant damage to environmental, social, and economic systems, especially agricultural areas. This study is an estimate of drought intensity and frequency in terms of annual precipitation. This study aims to assess hydrological drought (SPI 12) events within Sulaimanya province, Iraq, using the standardized precipitation index (SPI) to analyze annual precipitation data from 15 weather stations covering the period from 2003 to 2022. Determine the duration of the hydrological drought. The results showed that 53% of the studied years were classified as wet, while 47% were classified as dry based on the standard value of the rainfall index at 12 months. Stations Sulaimanya, Chamchamal, Halabja, Kalar, and Khanaqin exhibit the most significant rainfall deficits, exceeding 25%, indicating severe drought. Conversely, stations in Darbandikhan, Dukan, Saidsadq, Qaradakh, Qaladza, Mawat, and Kfry display moderate rainfall deficits ranging from 20% to 25%. Less than a 20% rainfall deficit is seen in sites Penjwen, Chwarta, and Rania, indicating a negligible departure from the long-term average rainfall. The southern part of the study area, known as Garmian, receives less annual rainfall. Compared to the northern part, the effect of drought is more pronounced in the southern part of the study area when the annual rainfall decreases. The annual rainfall deficit was assessed relative to the 20-year average rainfall for each station. The study observed changes in rainfall patterns across meteorological stations in the study area.

***Keywords*: drought, rainfall, SPI, Deficiency, Sulaimanya.**

INTRODUCTION

Drought is a significant environmental issue affecting agriculture, water resources, ecosystems, and human communities. Identifying drought-related research gaps is crucial to advancing our understanding and developing effective mitigation and adaptation strategies. The importance of drought has increased, especially in recent years, due to the changing climate patterns on Earth. Forecasts suggest that, with the shift in the hydrological cycle and increasing global temperatures, droughts are expected to become more frequent and severe [1]. One of the biggest threats to agricultural production is the reduced productivity of rain-fed crops. The issue of water scarcity in drought-stricken nations is worsened by the increased dependence on irrigation [1]. Predicting the start, length, strength, and reach of a drought is a challenging task due to its complex nature as a natural disaster [2]. Forecasting and successfully handling drought pose an equal level of difficulty. Examples of broad impacts include negative effects on the social, environmental, and economic conditions of the affected regions. Rainfall is the main source of life in arid and semi-arid areas. Low precipitation, however, results in a decline in agricultural production [3]. Droughts are defined as extended decreases in precipitation over extended periods of time. They pose significant issues because they result in water shortages, which are necessary to support the needs of the environment, agriculture, and the human population. Water resources that are necessary for several businesses, including agriculture, irrigation, and basic sustenance, have been impacted by the recent droughts in Iraq [1]. The effects of drought can occasionally pollute water supplies [4]. The need for agricultural goods has surged due to the growing population's rising demand for food. The continued impact of reduced rainfall and the harmful consequences of drought are still presenting challenges [5]. The SPI is frequently used as a statistic to assess dry conditions in various climate regions. The adaptable SPI calculation method and simple approach allow for the evaluation of rainfall deficits over different periods, providing a detailed description of drought occurrences. Research conducted in the Al-Jafara Plain in Libya found that there was a higher occurrence of mild drought and moderate humidity compared to severe drought. Ahmed Ibrahim's research further emphasizes the seriousness of drought [6]. During the study period (1984-2015), the SPI was utilized to analyze drought periods in the Zarqa River Basin, Jordan, revealing a significant occurrence of 47.7%, where multiple years in a row saw total lack of rainfall at every station. Surprisingly, only 2011 and 2012 experienced wet weather at all stations. They also noted that during the research, the number of wet regions decreased by 0.8%, demonstrating the usefulness of the SPI in identifying long-term dry patterns [7]. One powerful and useful method that greatly aids in determining drought conditions is remote sensing [8]. Although there has been much research on drought, little attention has been paid to the impact of reduced rainfall. This study aimed to use the SPI 12 index to monitor drought in Sulaymaniyah Governorate during 2003-2022.

Materials and Methods

Study area

The study area is situated in the northeastern region of Iraq, positioned between specific longitudes 46°36E to 44°47E and latitudes 34°28N to 36°40N (Figure 1). Sulaimanya Governorate spans an area of 21,243 km^2. The climate of the study area is classified as arid and semi-arid [15]. Table 1 shows all station longitudes and latitudes. Climate data were collected from 15 climate stations across the region (Table 2 and Table 3) from the period 2003 to 2022.

Table 1: for all locations (longitudes and latitudes)

Station Name	Longitude	Latitude	Station Name	Longitude	Latitude
Sulaimanya	45°27 E	35°33 N	Rania	44°55 E	36°15 N
Penjwen	45°56 E	35°37 N	SaidSadq	45°52 E	35°21 N
Chamchamal	44°49 E	35°31 N	Qaradakh	45°23 E	35°18 N
Chwarta	45°33 E	35°43 N	Qaladza	45°07 E	36°10 N
Halabja	45°59 E	35°10 N	Kfry	44°57 E	34°41 N
Mawat	45°24 E	35°54 N	Kalar	45°18 E	34°37 N
Darbandikhan	45°41 E	35°06 N	Khanaqin	45°23 E	34°21 N
Dukan	44°57 E	35°57 N			

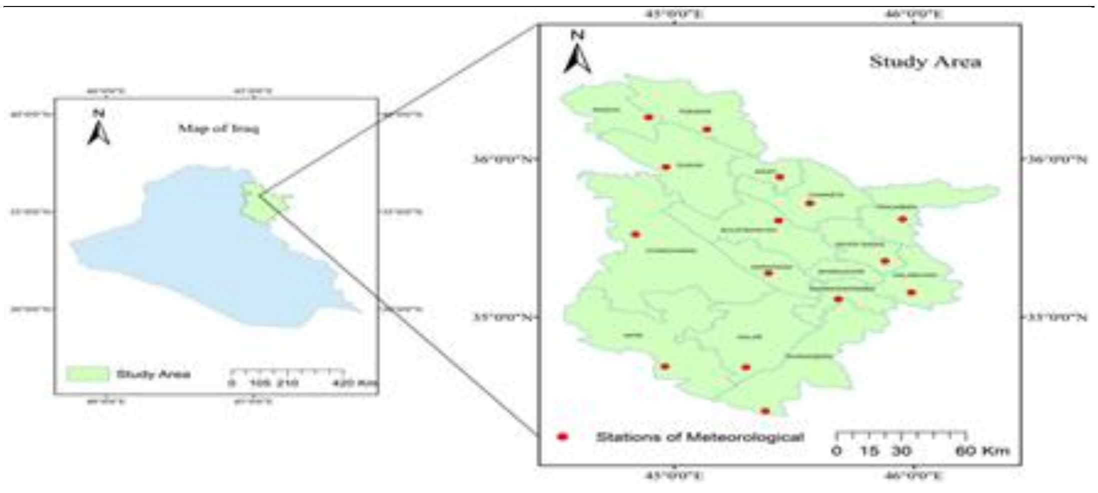


Figure 1: Study Site Area

Table 2: Annual Precipitation mm year^{-1} (2003- 2022)

Years	Sulaimanya	Penjwen	Chamchamal	Chwarta	Halabja	Mawat	Darbandikhan
2003	810.8	1315.2	487.3	813.3	841	940.3	652.3
2004	752.4	1215.5	545.8	864.6	893.6	929.6	708.7
2005	545.1	983.5	504.4	619.6	738.5	672.1	546.4
2006	801.2	1402.8	630.7	943.7	942.5	1072.7	530.8
2007	590.5	910.4	334.8	565.3	577.1	591.4	501.8
2008	380.3	535.9	175	449.8	344.4	368	295.7
2009	613.5	977.2	336.7	678.5	672.5	667.3	584.2
2010	543.1	925.2	407.7	665.3	700.8	616.3	605.7
2011	648.6	1000.9	341.5	731.1	654.2	720.9	601
2012	649.3	1161.5	338.9	720.3	734.4	868.3	546.9
2013	501.4	1143.5	508.3	706.2	641.8	757.8	645.2
2014	653.3	929.6	520.6	765.3	520.4	727.7	533.8
2015	722.3	1042.2	531.6	743.5	653.3	813.5	706.6
2016	655.3	1140.8	572.1	776	511.3	857.9	582.4
2017	484.8	844.8	322.4	619.2	454.6	502.8	410
2018	1234.2	1705.9	801.3	1200.5	898.4	1247.6	880.6
2019	1032.5	1371.8	746.3	1042.5	803.9	1011.2	885.6
2020	739.6	1092	577.9	1141	503.2	796.4	558.4
2021	289.9	592.7	254.8	572.5	254	436.6	232
2022	516.4	870.5	357.4	989.5	410.5	591.6	412.2
Mean	658.2	1058.1	464.8	780.4	637.5	759.5	571.0

Table 3: Annual Precipitation mm year^{-1} (2003–2022)

Years	Dukan	Rania	Saidsadq	Qaradakh	Qaladza	Kfry	Kalar	Khanaqin
2003	696.2	903.7	645	773	976.5	230.2	329.6	164.5
2004	863.7	997.7	580.5	792.5	1000.5	335.9	333.7	238.3
2005	645.5	690.3	415.6	695.5	514.5	318.9	378.7	313.7
2006	820.3	1029.2	687.6	972	1003.3	399.8	413.8	354.1
2007	411	562.3	417.7	655	594.5	335.9	352.6	300.5
2008	282.1	365.5	310.7	301.5	468.5	207.2	156.0	132.1
2009	495.6	644.2	542.2	512	728.5	288.4	310.9	293.2
2010	348.4	539.5	508.1	653.4	512.5	194.9	223.0	193.4
2011	510.1	701.1	504.8	675.5	714	198.8	239.4	318.0

2012	544.3	729	558.5	861	788	277.1	274.2	201.9
2013	556.6	775.6	580.5	882	844.5	322.2	342.6	180.8
2014	586.2	731.3	532	713	735.5	287.9	316.0	359.1
2015	648.3	755.9	633.2	1050	801	367.5	336.8	370.5
2016	683.6	741.4	622	1027	852	320.5	363.7	316.4
2017	359.6	475.1	471.9	697.5	461.5	198.8	207.4	224.1
2018	1031.4	1289.9	987.8	1622.5	1272	420.9	437.0	462.2
2019	760.6	1232.4	800.9	1352.5	1034.5	361.6	405.1	339.0
2020	510.2	872.3	552.4	1118.3	709.5	246.8	259.5	260.2
2021	325	510.5	185.8	415.5	502.5	137.4	128.5	160.2
2022	361	634.7	370.2	838.7	602.5	271.3	306.6	202.9
Mean	572.0	759.1	545.4	830.4	755.8	286.1	305.8	269.3

Precipitation Index

The Standardized Precipitation Index (SPI) is a pivotal indicator in drought characterization, initially proposed by Mckee**[9].** It assesses dry and wet periods based on the rainfall deficit [10]. Essentially, the SPI evaluates the impact of rainfall deficits on various hydrological factors such as soil moisture, river flow, reservoir reserves, and water levels across different time scales ranging from 1, 3, 6, 9, 12, 24 and 48 months [9]. This indicator enables the estimation of drought effects and facilitates severity comparisons across different locations worldwide and over varied time spans, utilizing rainfall data collected over 30 years [11]. Positive SPI values indicate precipitation levels above the median, whereas negative values signify precipitation deficits. By comparing SPI values with those listed in Table No. 3, the severity of the drought can be estimated. Dry periods are identified during intervals where the SPI value is negative

Table 4: classification of drought according to SPI values.

Classification	SPI Value
Extremely wet	≥ 2
Severely Wet	1.5 to 1.99
Moderately wet	1 to 1.49
Mild wet	0 to 0.99
Mild drought	-0.99 to 0
Moderately drought	-1.49 to -1
Severely drought	-1.99 to -1.55
Extremely drought	-2 ≤

In this study, drought intensity and frequency were assessed across the 15 study stations on a 12-month annual index (SPI 12) from 2003 to 2022. This equation was used to determine the SPI value [12].

SPI 12=X_i - X_m / SD

X_i : rainfall for the year

X_m: 20-year average total rainfall

SD: standard deviation

SD = $\sqrt{\frac{\sum(Xi-Xm)^2}{n-1}}\sqrt{\frac{\sum(Xi-Xm)^2}{n-1}}$ **n:** number of years

Annual rainfall deficit

The annual rainfall deficit refers to the shortfall in precipitation recorded at a specific station over a year compared to its long-term average. This deficit occurs when the total rainfall for the year is below the average total rainfall calculated over 20 years. [13].to calculate the annual rainfall deficit, follow these steps:

Rainfall deficit = X – Y

X: 20-year average total rainfall

Y: Total rainfall for the year

Results and Discussions

Standardized Precipitation Index

Figures 2 to 4 demonstrate the SPI 12 values for each station across all years of the study. These figures depict the occurrence of both dry and wet periods within the study area throughout the study perio

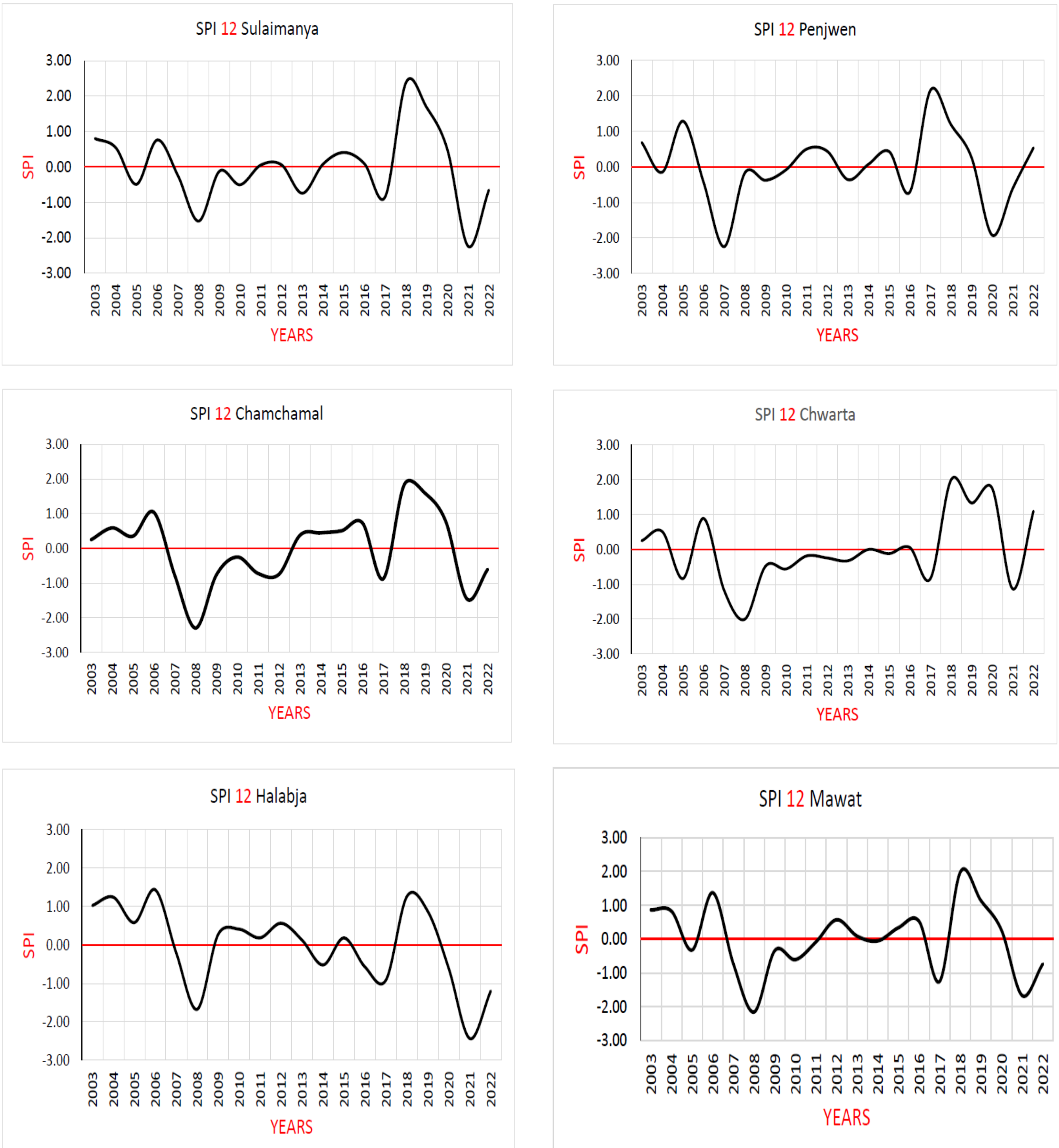


Figure 2: Variations of SPI 12 values with drought years during 2003-2022.

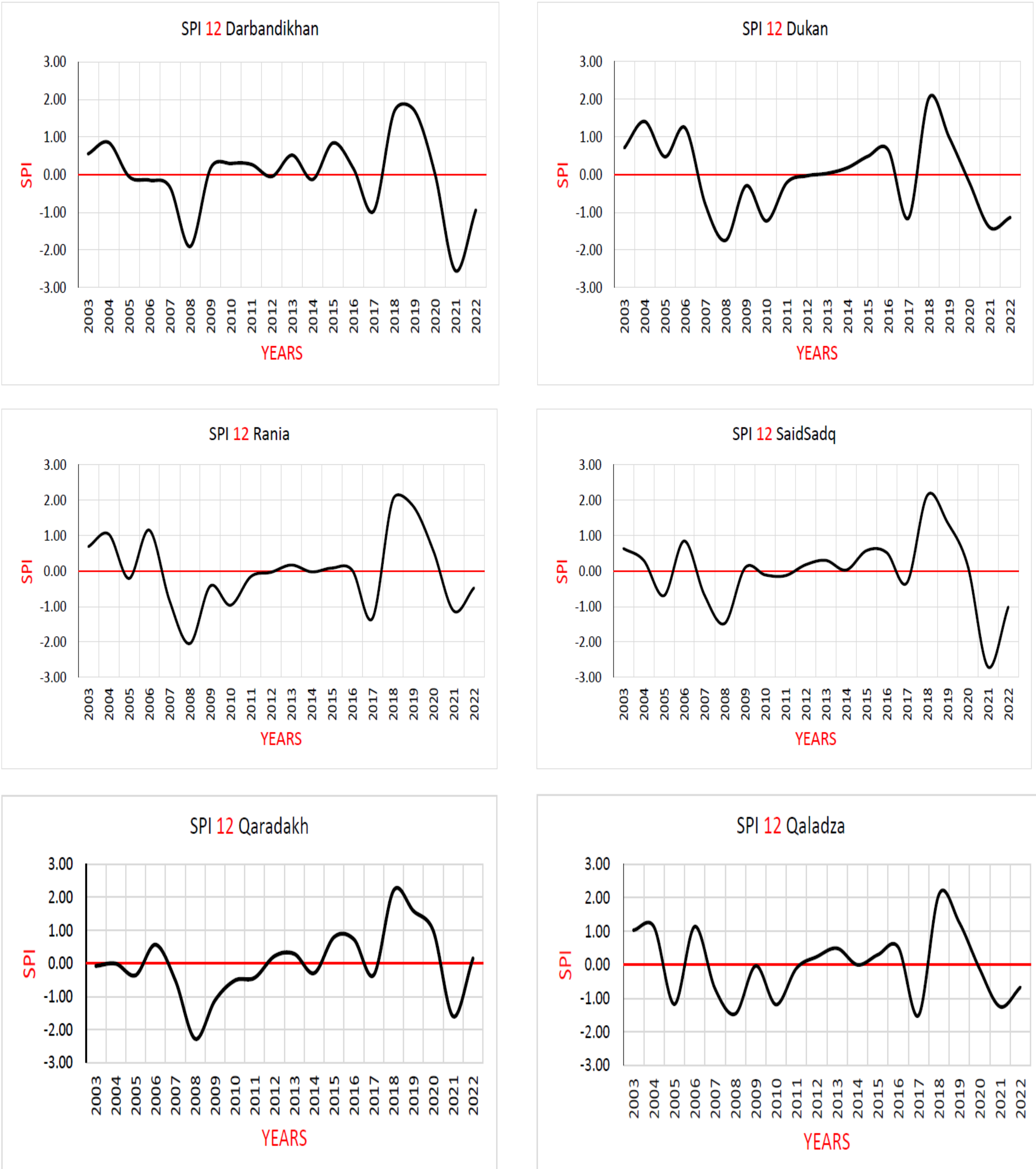
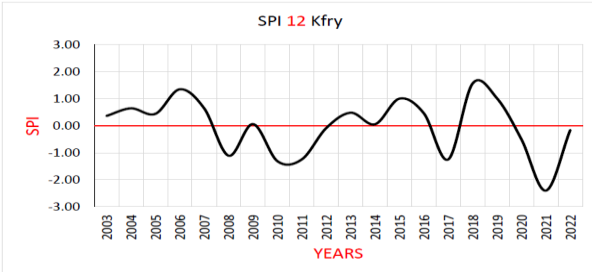
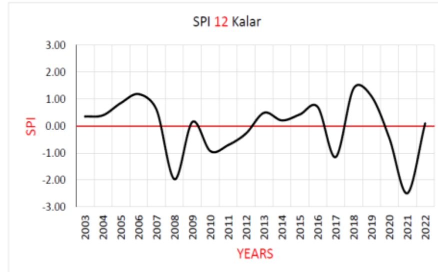


Figure 3: Variations of SPI 12 values with drought years during 2003-2022.





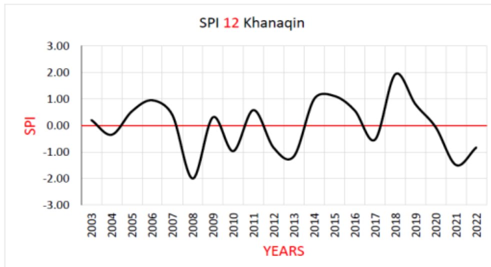


Figure 4: Variations of SPI 12 values with drought years during 2003-2022.

Figures 2 to 4 show each station in the study area, and the assessment of SPI 12 values as drought indicators is shown. Drought conditions between 2003 and 2022 were observed in all stations during the study period, which had a significant impact throughout the study area. In Sulaimanya station, 2005, 2007, 2009, 2010, 2011, 2012, 2013, 2017, and 2020 are mild drought years, but the 2008 severe drought and the 2021 extreme drought. In Penjwen station, 2004, 2006, 2007, 2009, 2010, 2013, 2017, 2016, and 2021 are mild drought years, but 2008 is extremely drought, and 2020 is severe. In Chamchamal station, 2007, 2009, 2010, 2011, 2012, 2017, and 2021 are mild drought years, but 2008 is extremely droughty and 2020 is a severe drought. At Chwarta station, 2005, 2009, 2010, 2011, 2012, 2013, 2015, and 2017 experienced mild drought, while 2007 and 2021 saw moderate drought, and 2008 had extreme drought. In Halabja station, the years 2007, 2014, 2016, 2017, and 2020 experience mild drought, while 2008 has severe drought, 2021 has extreme drought, and 2022 has moderate drought. At Mawat station, the years 2005, 2007, 2009, 2010, 2011, 2014, and 2022 experience mild drought, while 2008 is exceptionally dry, 2017 is moderately dry, and 2021 faces severe drought. 2005, 2006, 2007, 2012, 2014, 2017, and 2022 saw mild drought in Darbandikhan station, while 2008 experienced severe drought and 2021 had an extreme drought. In Dukan station, the years 2007, 2009, 2011, 2012, and 2020 experience mild drought, while 2010, 2017, 2021, and 2022 face moderate drought, with 2008 being a severe drought. In Rania station, 2005, 2007, 2009, 2010, 2011, 2012, 2014, and 2022 experienced mild drought, with 2008 being significantly severe, while 2017 and 2021 had moderately severe drought. In SaidSadq station, 2005, 2007, 2010, 2011, and 2017 experienced mild drought, while 2008 and 2022 saw moderate drought, and 2021 had severe drought. During 2003, 2004, 2005, 2007, 2010, 2011, 2014, and 2017, Qaradakh station experienced mild drought, while 2008 and 2021 saw severe drought, and 2009 had moderate drought. At Qaladza station, the years 2007, 2009, 2011, 2020, and 2022 experience mild drought, while 2005, 2008, 2010, and 2021 face moderate drought, and 2017 endures severe drought. At Kfry station, there are mild droughts in 2012, 2020, and 2022; moderate droughts in 2008, 2010, 2011, and 2017; a severe drought in 2006; and an extreme drought in 2021. During the years 2010, 2011, 2012, and 2020, Kalar station experienced mild drought conditions, while the years 2006 and 2008 were marked by severe drought. 2017 the area faced moderate drought, and 2021 brought extreme drought. In Khanaqin station, the years 2004, 2010, 2012, 2017, and 2020 experienced mild drought, while 2008 had an extremely severe drought, and the years 2013 and 2021 had moderate drought.

Most stations experienced a moderate drought. The analysis highlights significant variations in drought intensity and rainfall patterns across different regions of the study area. In particular, the southern and southwestern regions experience more severe drought than the northern and northeastern regions, indicating differences in rainfall within the study area's high and low temperatures. Understanding this regional climate dynamic is crucial for drought impact management and adaptation strategies. It emphasizes the importance of accurate risk assessment and the development of targeted adaptation measures to mitigate the effects of drought in vulnerable areas. By recognizing and addressing these complexities, policymakers and stakeholders can better prepare for and respond to drought events in a more informed and strategic manner. These results are in agreement with [13].

Depending on the SPI values, there are dry years and wet years. The SPI values for each station were classified to distinguish between wet and dry years, as listed in Table 4. This provides an analysis of the frequency of occurrence for each of the eight identified type

Table 5: Classification of SPI 12 values for all stations

Station Name	No. of years of registration	Extremely wet	Severely Wet	Moderately wet	Mild wet	Number of wet years	Percentage of wet years	Extremely drought	Severely drought	Moderately drought	Mild drought	Number of dry years	Percentage of dry years
Sulaimanya	20	0	2	0	9	11	55%	1	1	0	7	9	45%
Penjwen	20	0	0	2	7	9	45%	1	1	0	9	11	55%
Chamchamal	20	0	2	1	8	11	55%	1	1	0	7	9	45%
Chwarta	20	0	2	2	5	9	45%	1	0	2	8	11	55%
Halabja	20	0	0	4	8	12	60%	1	1	1	5	8	40%
Mawat	20	0	1	2	7	10	50%	1	1	1	7	10	50%
Darbandikhan	20	0	2	0	9	11	55%	1	1	0	7	9	45%
Dukan	20	1	1	1	7	10	50%	0	1	4	5	10	50%
Rania	20	1	1	2	5	9	45%	1	0	2	8	11	55%
SaidSadq	20	1	0	1	10	12	60%	1	0	2	5	8	40%
Qaradakh	20	1	1	0	7	9	45%	1	1	1	8	11	55%
Qaladza	20	1	0	4	5	10	50%	0	1	4	5	10	50%
Kfry	20	0	1	2	8	11	55%	1	1	4	3	9	45%
Kalar	20	0	0	2	10	12	60%	1	2	1	4	8	40%
Khanaqin	20	0	1	2	8	11	55%	1	0	2	6	9	45%
Mean							53%						47%

The analysis of SPI classification in the study area reveals a significant distribution between dry-temperate and humid-temperate conditions. Dry years comprised 47% of the total period examined, contrasting with wet years (53%). Notably, stations like Halabja, SaidSadq, and Kalar consistently registered higher percentages of wet years at (60%), while Penjwen, Chwarta, Rania, and Qaradakh exhibited lower percentages at (45%). Conversely, Penjwen, Chwarta, Rania, and Qaradakh experienced the highest occurrences of dry years (55%), in contrast to Halabja, SaidSadq, and Kalar with 40% of dry years. Specific extreme conditions were observed, with very humid years occurring at Dukan, Rania, SaidSadq, Qaradakh, and Qaladza stations for one year. Conversely, very severe drought conditions were noted at most stations except Dukan and Qaladza for a single year. Furthermore, stations like Kalar and SaidSadq had the most moderately humid years with a total of 10, whereas Kfry, Rania, and Chwarta had 5 years. On the other hand, Penjwen recorded the highest number of moderately dry years at 9, with Kfry having 3 years. The stations of SaidSadq, Halabja, and Kalar experienced the highest wet years at 12, while Penjwen, Chwarta, Rania, and Qaradakh had 11 dry years. The discrepancies observed across the years studied contribute to the variability in

Occurrences at different stations, highlighting the intricate dynamics of drought and moisture conditions within the study area over the specified timeframe. These results are aligned with [14]. During the study period, the most common classification is within the SPI classification to determine wet and dry years. The variability in the SPI 12 classification across the study area can be attributed to factors like geographical location, climate systems, local weather patterns, climate change, natural variability, and land use changes. Understanding these factors is crucial for assessing drought risk and implementing effective water management strategies

Annual rainfall deficit

After applying the equation, the rain deficit was calculated for each drought year at each station within the study area, extending from 2003 to 2022. The analysis revealed the presence of a rainfall deficit, as shown in Table 4, which displays the values of drought, drought sustainability, and drought severity. The percentage of the deficit in annual rainfall

Table 5: shows the values of rain deficit “M” (mm), drought sustainability “L” (years), drought severity “I” (mm. $year^{-1}$), and percentages of rainfall deficit “Per.”.

Station Name	M	L	I	Per.	Station Name	M	L	I	Per.

Sulaimanya	1414.16	8	176.77	27%	Dukan	1588.18	11	144.38	25%
Penjwen	2025.87	11	184.17	17%	Rania	1787.5	13	137.5	18%
Chamchamal	1314	9	146	31%	SaidSadq	1194.8	10	119.48	22%
Chwarta	1532.7	13	117.9	15%	Qaradakh	2253.02	11	204.82	24%
Halabja	1524	8	190.5	30%	Qaladza	1769.9	11	160.9	21%
Mawat	1702.03	11	154.73	20%	Kfry	639.9	9	71.1	25%
Darbandikhan	1142	10	114.2	20%	Kalar	651	7	93	30%
Khanaqin	739.9	10	73.99	27%					

5 provides valuable insights into the severity and variability of drought conditions across the study area, illustrating the highest, average, and minimum rates of rainfall deficit among stations. Sulaimanya, Chamchamal, Halabja, Kalar, and Khanaqin exhibit the most significant rainfall deficits, exceeding 25%, indicating severe drought events during the study period. These deficits signify a notable departure from the long-term average rainfall. Conversely, stations, Darbandikhan, Dukan, Saidsadq, Qaradakh, Qaladza, Mawat, and Kfry display moderate rainfall deficits ranging from 20% to 25%, representing typical deviations observed in drought years, although not as extreme as the highest deficits. Less than a 20% rainfall deficit is seen in sites Penjwen, Chwarta, and Rania, indicating a negligible departure from the long-term average rainfall. Stations with higher average rainfall experience higher annual rainfall deficits due to rainfall variability, drought sensitivity, hydrologic characteristics, and climate change effects. Recognizing and understanding these dynamics is essential for effective water resource management, risk mitigation strategies, and adaptation efforts in the face of climate change. These deficiencies might not immediately suggest a drought concern, but understanding general rainfall patterns and identifying regions at risk from future droughts depends on them. Understanding the leading causes of inadequate rainfall is essential to developing strategies for managing and reducing the consequences of drought and determining how well the studied region can respond to shifting trends in rainfall. These findings support [14].

Conclusions

The data from the Standardized Precipitation Index (SPI) show notable differences in the degrees of moisture and aridity over the study area, clearly differentiating between times of moderate wetness and times of moderate dryness. Stations with higher average rainfall experience more noticeable annual rainfall deficits than those with lower average rainfall. Changes in land use, natural cycles, global warming, and the local climate. Understanding these traits is essential to assessing the effects of drought risk and developing adaptive strategies. The findings highlight the significance of considering local climate dynamics in the development of water management.

References

[1] **Jalab, J. and Sheikho, T.** 2013. Estimating the severity of seasonal and annual drought and its frequency in some locations in the region Southern Syria. Tishreen University Journal for Research and Scientific Studies - Biological Sciences Series Vol. 35 No. 1 pp41-54

[2] Tsatsaris, A.; Kalogeropoulos, K.; Stathopoulos, N.; Louka, P.; Tsanakas, K.; Tsesmelis, D.E.; Krassanakis, V.; Petropoulos, G.P. Pappas, V. and Chalkias, C. 2021.Geoinformation Technologies in Support of Environmental Hazards Monitoring under Climate Change An Extensive Review. ISPRS Int. J. Geo-Inf. 10, 94

[3] **Abdel Ghani, E.T.; Al-Shamary, W.F.A. and Abdulhamed, I.M.** 2022. General review of water harvesting in arid and semi-arid areas. Kirkuk University Journal for Agricultural Sciences, Vol. 13, No. 3, pp (302-320)

[4] **Ali, D.A.; Abdulrahman, N.M. and Rahem, B.R.** 2023. Some Heavy Metals Status and Water quality parameters of Darbandikhan Dam, Sirwan and Tanjaro rivers. Kirkuk University Journal for Agricultural Sciences, Vol. 14, No. 1, pp (131-150)

[5] **Hedres, I.H.; Khalaf, A.A. and Shihab, M.R.** 2022. Using of SEBAL model for estimating net solar radiation and land surface temperature in the Dyala River Basin. Kirkuk University Journal for Agricultural Sciences, Vol. 13, No. 1 pp (48-61)

[6] **Ekhmaj, A.I. and El-miludi, A.M.M.** 2019. Analysis of Meteorological Drought Using Standard Precipitation Index for Some regions in Jafara Plain, Libya During 1962-1999. the Libyan Journal of Agriculture Volume. 24, No. 1, pp 1-17

[7] **Yusra, A. and Zugul, M.**2018. Analysis of Drought Periods in the Zarqa basin, Using Standard Precipitation Index (SPI) and geographic information system (GIS) during 1984-2015 Associate Professor, Department of Geography, University of Jordan, Amman. w.alhusban@ju.edu.jo

[8] AlJawwadi ,T.A.T.D. and Qubaa, A.R. 2022 Management of irrigated soil by rotary sprinklers using remote sensing techniques. Kirkuk University Journal for Agricultural Sciences, Vol. 13, No. 2, pp (15-22)
[9] **McKee, T.B., Doesken, N.J. and Kleist, J.** 1993. The relationship of drought frequency and duration to time scales. 8th Conference on Applied Climatology, 17-22 January, Anaheim, CA, pp. 179-184.
[10] **Richard, R. and Heim, J.R.** 2002. A Review Of Twentieth-Century Drought Indices Used In The United States. American Meteorological Society.
[11] **Logan, K.E.; Brunsell, N.A.; Jones, A.R. and Feddema, J.J.** 2010. Assessing Spatiotemporal Variability Of Drought In The US Central Plains. Journal Of Arid Environments. (74), 247-255.
[12] **Bhattacharya, Sh.; Halder, S.; Nag, S.;Roy, P.K. and Roy, M.B.** 2021. Assessment of Drought Using Multi-Parameter Indices. https://www.researchgate.net/publication/351 101191
[13] **Kasim, S.M.; Yunis, A.M. and Alghni, O.M.A.** 2021. Temporal and Spatial Analysis of Drought Using the Standard Precipitation Index for the Northwestern Region of Iraq. Al-Rafidain Engineering Jornal Vol.26, No. 1, pp115-127
[14] **Rasheed, A.M.M.** 2010. Analysis of Rainfall Drought Periods in the North of Iraq Using Standard Precipitation Index (SP1). Al-Rafidain Engineering Jornal Vol.18, No. 2, pp60-72
[15] **Najmaddin, P.M.; M.J. Whelan and H. Balzter.** 2017. Estimating daily referenceevapotranspiration in a semi-arid region using remote sensing data, Remote Sensing,(779): 1-20

تقييم شدة الجفاف الهيدرولوجي وتكراره باستخدام SPIفي محافظة السليمانية، العراق(2003–2022).

الان رحمان مصطف[1] **1ظاهر خليل علي[1]** **دلشاد رسول عزيز[1]**

[1] قسم علوم التربة والموارد المائية ،كلية الزراعة ، جامعة كركوك ، كركوك، العراق.

الخلاصة

يعتبر الجفاف ظاهرة متكررة، وهي سمة طبيعية للمناخ، وأحد المخاطر الطبيعية الكبرى التي يتعرض لها العراق مرارا ، مما يسبب أضرارا كبيرة للنظم البيئية والاجتماعية والاقتصادية، وخاصة المناطق الزراعية. هذه الدراسة عبارة عن تقدير لشدة الجفاف وتكراره بالأعتماد على هطول الأمطار السنوي. تهدف هذه الدراسة إلى تقييم حصول الجفاف الهيدرولوجي *SPI 12* ضمن محافظة السليمانية، العراق، باستخدام مؤشر الهطول القياسي (*SPI*)من خلال تحليل بيانات الهطول السنوية من 15 محطة انواء جوية تغطي الفترة من 2003 إلى 2022. وأظهرت النتائج أن 53% من السنوات المدروسة صنفت على أنها رطبة، في حين صنفت 47% على أنها سنوات جافة على أساس القيمة المعيارية لمؤشر هطول الأمطار عند 12 شهرا. كان تأثير الجفاف أكثر وضوحاً في الجزء الجنوبي من منطقة الدراسة حيث تنخفض الأمطار السنوية. تم تقييم العجز السنوي في هطول الأمطار بالنسبة إلى متوسط هطول الأمطار لمدة 20 عامًا لكل محطة وكانت محطات السليمانية و جمجمال و حلبجة و كلار و خانقين تعرضت الى عجز المطري تجاوزت 25% وبهذا تكون ضمن العجز الشديد ، دربنديخان و دوكان و سيدصادق و قرداغ و قلعةدزة و كفري تقع ضمن العجز المتوسط حيث بلغت 20–25% بينما عجز المطري قليل (اقل من 20%) في محطات بينجوين و جوارتا و رانيه بينما المحطات ، يتلقى الجزء الجنوبي من منطقة الدراسة، المعروف باسم كرميان، أمطاراً سنوية أقل مقارنة بالجزء الشمالي، ويكون تأثير الجفاف أكثر وضوحاً في الجزء الجنوبي من منطقة الدراسة عندما تنخفض الأمطار السنوية. تم تقييم العجز السنوي في هطول الأمطار بالنسبة إلى متوسط هطول الأمطار لمدة 20 عامًا لكل محطة ، ولاحظت الدراسة تغيرات في أنماط هطول الأمطار عبر محطات الأرصاد الجوية في منطقة الدراسة.

الكلمات المفتاحية : الجفاف ، تساقط الأمطار ، دليل المطر القياسي، العجز المطري ، السليمانية.