Jordan Journal of Civil Engineering, Volume **18**, No. **4**, **2024**
DOI: https://doi.org/10.14525/JJCE.v18i4.09

Jordan Journal of Civil Engineering

Journal homepage: https://jjce.just.edu.jo

Using Statistical Methods to Analyze 32 Years of Rainfall Data in Amman, Jordan

Mohammad Almawas [1]**,** ***Mastura Azmi*** [1]***,** ***Mousa Bani Baker*** [2]

[1] *School of Civil Engineering, University Sains Malaysia, Engineering Campus, 14300, Nibong Tebal, Penang, Malaysi.*
* *Corresponding Author. E-Mail: cemastura@usm.my*
[2] *Civil Engineering Program, College of Engineering, Al Ain University, Al Ain, United Arab Emirates.*

ARTICLE INFO

Article History:
Received: 3/2/2024
Accepted: 23/9/2024

ABSTRACT

The construction of hydraulic structures, bridges, culverts, canals, stormwater sewers, and road drainage systems relies on rainwater. Calculated capacities and associated design of required structures based on collected data mandate that these structures can operate properly under various weather conditions and discharge the water that they will be exposed to. Hydrological studies observe flood hazards and plan water resource management using rainfall data. Four rain gauge stations near Amman-downtown (Ras Al-Ain area) were selected for statistical analysis. To comprehend normal, deficiency, excess, and seasonal rainfall of the chosen circle headquarters, 32 years of daily rainfall data are used. This analysis predicts rainfall and plans water resource management. Moreover, it helps determine return periods. This approach aids disaster and crisis management planners and decision-makers to analyze water availability and develop strategies for its storage using statistical measures to assess the variability of monthly and yearly rainfall. By analyzing rainwater for 32 years, the results revealed that Weibull method is 99% in agreement with the average rainfall for all selected stations. Expected maximum discharge for different return times (return times range from 5 to 100 years) was used to fit statistical distributions of (2156.1 mm, 2656.4 mm, 3270.9 mm, 3741.2 mm, and 4221.5 mm), which was identical to the average annual maximum precipitation amount based on positioning methods for all stations. As a result, this technique provides the best matching annual precipitation. Findings revealed that rainfall pattern exhibits irregularity and the probability distribution that provided the best match was determined by minimizing the discrepancy between the observed values and the estimated values.

Keywords: Floods, Amman, Rainfall patterns, Return periods, Statistical analysis, Hydraulic structures.

INTRODUCTION

Floods are among the significant challenges of the 21st century related to climate change. They are responsible for about two-thirds of the total human losses incurred by natural disasters in the past 40 years (Loudyi & Kantoush, 2020). They account for about one-third of the associated economic damage. Floods can be identified as a mysterious, short-term event occurrence, sometimes near lakes, coasts, rivers, dams, or during limited precipitation (Sayers et al., 2013). In another definition, a flood is a tragedy in the atmosphere, ecosystem, and human life (Parkash, 2014). The hydrological process is stepped up by climate change, contributing to more precipitous shifts in the storms' size, frequency, and intensity (Apurv et al., 2015), where climate change, melting ice, and storms have caused great flooding of rivers and valleys, in addition to the factors supporting the occurrence of flooding, such as urban development of areas, the density of random construction, failure of sewerage network, shrinking vegetation, … etc. of unplanned practices (Alhasanat, 2017). As a result, the community started creating flood-protection systems in high-risk areas to avoid floods, where the main aim of decision-makers is to prevent flooding and mitigate damage (Sayers et al., 2013). Rainfall is the primary and crucial source of water in any given geographical region. Therefore, it is crucial to use statistical analysis to forecast the likelihood of rainfall based on historical hydrological data. The use of frequency or probability distribution facilitates the establishment of a connection between the intensity of exceptional events, such as floods, droughts, and severe storms, and the frequency at which they occur (Armon et al., 2019). This enables the straightforward prediction of the likelihood of their recurrence over a certain period (Mohita Anand and Jai Bhagwan, 2010). By applying a frequency distribution model to a given dataset of hydrological data, it becomes possible to determine the likelihood of random parameter occurrences. To conform to the distribution, an analysis is conducted on the hydrological data, with a focus on examining the variability within the data *via* the use of statistical factors (Towfiqul Islam et al., 2021). Studies in Jordan have evaluated various satellite rainfall estimates (SREs), like TRMM and PERSIANN-CDR, highlighting their performance at different temporal scales (Al-Sheriadeh and Al-Sharman, 2024; Al-Saeedi et al., 2024; Arabeyyat et al., 2018). Additionally, research on the Amman-Zarqa Basin has assessed historical rainfall trends, future climate change projections, and sensitivity to flash floods, indicating changes in precipitation levels and temperature over time (Al Saodi et al., 2023; Ghumaid, 2023). Furthermore, investigations into synoptical weather variability in the Eastern Mediterranean region, including Jordan, have focused on identifying critical circulation patterns associated with extreme rainfall events, emphasizing the need for accurate risk estimation under climate change scenarios (Hoffmann, 2023).

This study takes a thorough approach to evaluating 32 years of rainfall data, particularly for Amman, Jordan, utilizing modern statistical approaches. Unlike prior studies that have examined larger geographic areas or shorter periods (Al Daraien & Al Atawneh, 2021; Odeh et al., 2022), this research stands out for its specific and extended emphasis on a particular location which focuses only on Amman, giving a meticulous analysis that is specifically relevant to the city's unique meteorological circumstances and urban issues. Unlike other studies (Al Saodi et al., 2023) that may include broader areas or many stations around Jordan, utilizing a 32-year rainfall data collection enables the detection of enduring patterns and recurring cycles, which may not be well captured by shorter studies. This prolonged duration provides a more profound understanding of possible changes in climatic patterns, especially about urbanization and the effects of climate change. A recent study (Shammout, 2023) has emphasized the influence of urbanization on water supplies in Amman. Moreover, this research study expands upon previous research by investigating the potential impact of these changes on long-term rainfall data, an aspect that has not been thoroughly investigated in previous studies.

STUDY AREA

The current study was conducted in Amman, Jordan. The area of the study area is 243.51 km^2. It is located from latitude 31°24" N to latitude 32°2" N and from longitude 35°35°67"E to longitude 36°43" E. Figure (1) shows the study area in Amman, Jordan. The downtown area is an old waterway, the "Amman Torrent," and rainwater is transported from the city centre to the waters of the Zarqa River. Daily-rainfall data was collected by the Jordanian Water Authority and subsequently analyzed for the period from 1991 to 2022. The data provided is used for the purpose of analyzing the probability of annual, monthly, and seasonal rainfall.

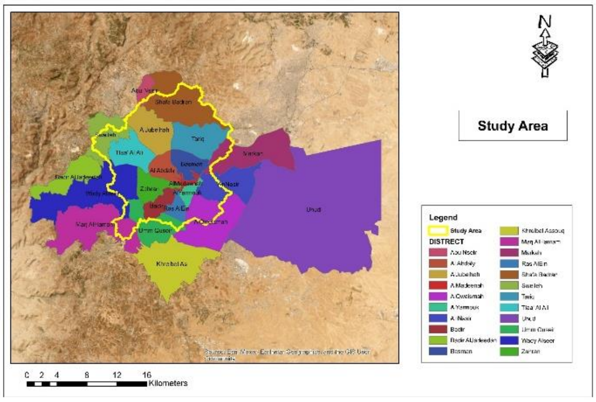

Figure (1): Study area in Amman, Jordan

Meteorological Stations

Despite the efforts made to reach the data of precipitation during the required periods for analysis, many meteorological stations were tracked throughout the study area and four stations were chosen to measure the precipitation inside the water basin, as shown in Figure 2, which presents the annual-rainfall data, offering a comparative view of precipitation levels across the region. These stations were strategically chosen to capture the variability in rainfall, providing essential insights for hydrological analysis and water resource management.

Table 1 shows the meteorological stations used within the study area and their coordinates and elevations above sea level.

Table 1. Meteorological stations within the study area

No.	Station	Longitude	Latitude	Height / m
1	Al-Hussein college station	31.966667	35.933333	845
2	Na'ur station	31.866667	35.833333	800
3	Sweileh station	32.033333	35.833333	887
4	Wadi Al-Seer station	31.950000	35.816667	750

Table 2 shows the maximum annual rainfall for all stations.

Table 2. Maximum annual rainfall for all stations

Year/Station	Amman Hussein College/ mm	Na'ur/ mm	Sweilih/ mm	Wadi Es-sir/ mm	Total Rainfall/ mm
1991	355	275.5	481.6	318.1	1430.2
1992	908.3	774.3	1258.3	975.3	3916.2
1993	433.1	390.4	635.6	442.8	1901.9
1994	324.6	166.3	399	417.5	1307.4
1995	392.7	216.8	423	532	1564.5
1996	332.2	150.2	334.5	486.6	1303.5
1997	388.5	394	445.6	510.9	1739
1998	390.5	348.7	483.5	558.3	1781
1999	176.2	128.3	212.6	110.4	627.5
2000	296.5	285.3	310.7	368.5	1261
2001	311.9	279.5	313.8	363.1	1268.3
2002	518	543.9	587.9	694.4	2344.2
2003	592.7	674.9	475	690.3	2432.9
2004	315.1	327.5	306.1	399.3	1348
2005	378.4	483.2	392.7	545.1	1799.4
2006	334.8	270.3	369.7	422.9	1397.7
2007	411.1	429.1	355.7	541.1	1737
2008	292.2	126.4	295.1	293.1	1006.8
2009	299.2	429.6	511.4	401.3	1641.5
2010	416	471.3	530.8	619.5	2037.6
2011	254.7	313.1	338.6	363.5	1269.9

2012	445	568.9	529.6	555.6	2099.1
2013	375.2	370.5	303.8	423.7	1473.2
2014	282	404.9	354.9	390.5	1432.3
2015	362.2	461.8	508.8	484.5	1817.3
2016	385.2	372.2	451.4	533.4	1742.2
2017	255.3	249.6	386.3	332.9	1224.1
2018	212.2	240.8	252.1	350	1055.1
2019	519.4	402.9	623.2	569.2	2114.7
2020	620.1	784.4	699.2	639.6	2743.3
2021	348	246.1	321.6	241	1156.7
2022	382.6	334	486.6	473.9	1677.1

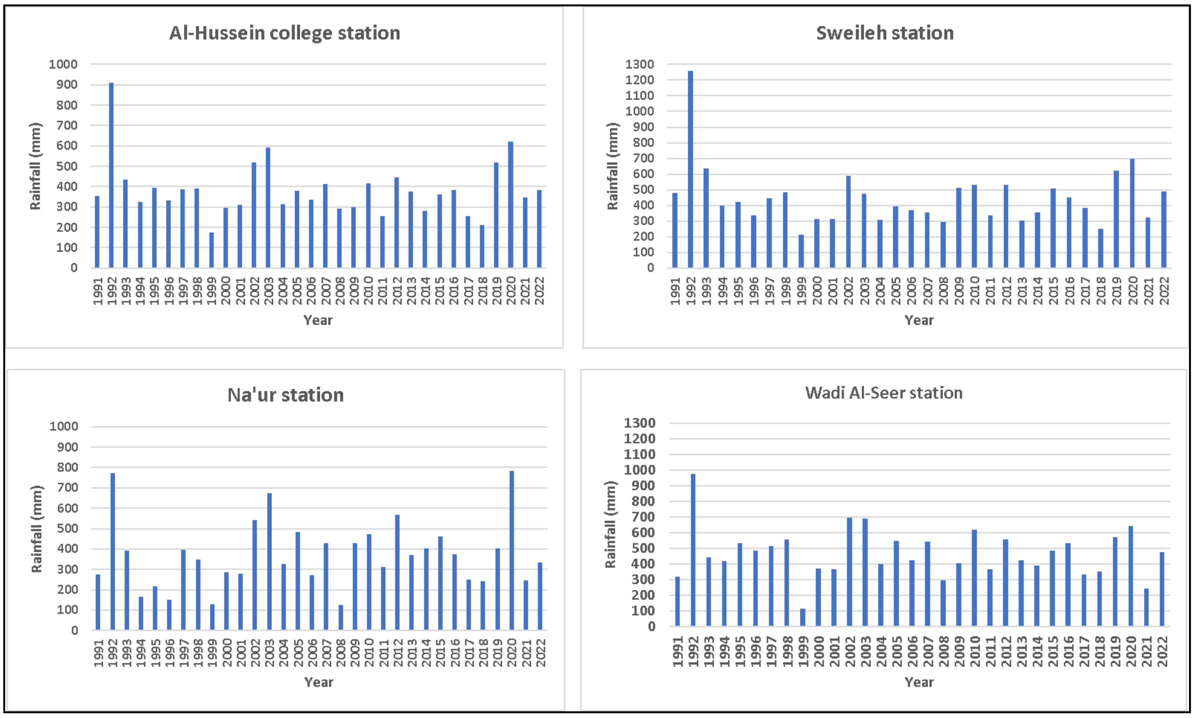

Figure (2): Annual rainfall of the selected stations

METHODOLOGY

The present study employs the rainfall statistics methodology and probability analysis techniques utilizing both plotting position and probabilistic methods. Precipitation frequency was analyzed by using the Gumbel distribution. The statistics of the highest rainfall in the research area from 1991-2022, along with 32-year precipitation data, have been considered during this process.

The statistical analysis and predictions about the probability of flood recurrence at different return times are based on the distribution of the highest Gumbel value in 100 years (Gumble, 1941):

The methodology used in this study consists of rainfall statistics (Table 3) and probability analysis using plotting position and probabilistic methods (Table 4).

Table 3. Formulae for statistical parameters (Arvind et al., 2017)

Description	Symbol	Formula	Explanation
Arithmetic Mean	Xavg	$\sum X_i/n$ (1)	X is the rainfall magnitude in mm, i=1, 2, to n and n is the number of years.
Standard deviation	Σ	$\left[\sum(X_i - X_{avg})^2/(n-1)\right]^{1/2}$ (2)	X is the rainfall magnitude in mm, i=1, 2, to n and n is the number of years.
Coefficient of Variation	Cv	$100 \times \left(\sigma/X_{avg}\right)$ (3)	Xavg is the mean; σ is the standard deviation
Coefficient of Skewness	Cs	$(1/\sigma_3) \times [(N/(N^2 - 3N + 2)] \times \sum(X_X - X_{avg})^2$ (4)	σ is the standard deviation; N = Total no. of years; Xavg is the mean; X is the rainfall magnitude in mm, i=1, 2 to n.

Annual-rainfall Analysis

The yearly-rainfall data is examined, and the distribution variance over the region is investigated using statistical factors. Various drawing positions and probability techniques are used to find the best match distribution strategy (Kareem Jebur, 2021).

Table 4. Plotting position and probabilistic methods (Arvind et al., 2017)

No.	Plotting position methods	Probabilistic methods
1	California = m/N (5)	Normal Distribution
2	Hazen = (m-0.5)/N (6)	Log-Normal Distribution
3	Weibull = m/(N+1) (7)	Pearson Type-III Distribution
4	Beard = (m-0.31)/(N+0.38) (8)	Log-Pearson Type-III Distribution
5	Chegodayev = (m-0.3)/(N+0.4) (9)	Extreme Value Type-I Distribution
6	Blom = (m-3/8)/(N+1/4) (10)	
7	Tukey = (3m-1)/(3N+1) (11)	
8	Gringorten = (m-0.44)/(N+0.12) (12)	
9	Cunnane = (m-0.4)/(N+0.2) (13)	
10	Adamowski = (m-1/4)/(N+1/2) (14)	

where, m is rank of the data and N = number of years.

The precipitation analysis is based on a set of precipitation data (1991-2022) generated by the HYFRAN-PLUS model. HYFRANPLUS (hydro frequency analysis) was used to fit the statistical distributions. It includes several powerful, flexible, and easy-to-use mathematical tools that can be used for statistical analysis of extreme events (Adlouni & Bobée, 2011). It was used to determine the expected maximum discharge for different return times (return times range from 5 years to 100 years) to fit statistical distributions, and more specifically for the many types of extreme events that may occur between distinct distributions of the data (Rad et al., 2022). To perform an accuracy test, the theoretical and experimental distributions were analyzed to determine which best matched the maximum discharge data provided by HYFRAN-PLUS. To determine whether the fit and accuracy of the data were statistically valid at different levels of significance across an acceptable P-value (value < 0.05), the following normal distribution tests were used, a log-normal distribution, a Pearson type-III distribution, a Log-Pearson type-III distribution, and a Gumbel distribution (Osei et al., 2021).

Monthly-rainfall Analysis

The Gumbel and normal distribution techniques are used, both of which coming from the realm of probabilistic approaches (Abdulrazzak et al., 2019). The statistics on the rainfall are organized into several intervals, each of which has a certain range (Abdelkarim & Gaber, 2019). The aggregated data was used to calculate the mean as well as the standard deviation. The values of chi-square are computed using the techniques, utilizing the probabilities that were acquired. It was determined that the approach that gave the chi-square value with the smallest absolute value best suited the distribution (Darwin et al., 2018).

The Weibull distribution is a sort of continuous probability distribution in which the quantities of rainfall are given a rank, and the probability density function is used to obtain the related probabilities (Sun et al., 2018):

$$X = \frac{M}{(N+1)} \tag{15}$$

where,

M and N represent the rank and total number of data used in the analysis.

The Gumbel distribution is a statistical tool that may be used to simulate the distribution of the extremities of several samples drawn from a variety of distributions (Arvind et al., 2017).

$$\boldsymbol{P(X)} = \left(\frac{-(\boldsymbol{a}+\boldsymbol{x})}{\boldsymbol{c}} - \boldsymbol{e} - \frac{-(\boldsymbol{a}+\boldsymbol{x})}{\boldsymbol{c}}\right) \tag{16}$$

$a = 0.45005\ \sigma - X_{avg}$ & $c = 0.7797\ \sigma$

where,

P(X) is the probability density function for the Gumbel method and Xavg represents the average rainfall in mm.

A relatively popular kind of continuous probability distribution is known as the normal distribution. The normal distribution is a statistical model that is used to describe real-valued random variables the distributions of which are unknown.

$B = 0.5[1 + 0.196854 |Z| + 0.115194 |Z|2 + 0.000344 |Z|3 + 0.015927 |Z|4$

$Z = (X - Xavg) / \sigma$, $F(X_i) = Bf$ or $Z < 0$ & $F(X_i) = 1 - Bf$ or $Z > 0$

The probability density function for the normal distribution method is as follows (Arvind et al., 2017):

$$\boldsymbol{X} = \boldsymbol{F}\,(\boldsymbol{X_i} + \boldsymbol{1}) - (\boldsymbol{X}) \tag{17}$$

X_i is the rainfall at any instant i = 1,2,3 to N.

RESULTS AND DISCUSSION

Annual-rainfall Analysis

The analysis included annual-rainfall data for the period 1991–2022 in the study area for four stations, as shown in Table 2. The rainfall data is arranged in descending order, and then several plot locations and probabilistic approaches are used to predict the return period. Using the precipitation return period equation, which was derived from the graphs of all plot patterns for each station, the expected precipitation amounts were calculated for each return period. This is shown in Table 5, which shows the maximum annual rainfall based on plotting position methods.

The results of the station analysis showed that the maximum annual rainfall was based on the methods of plotting locations and determining the most appropriate method of rainfall distribution for all stations, as shown in Table 5. It was observed in the case study analysis that the Gringorten method gave the lowest values which are 2075.6, 2539.5, 3153.2, 3617.3, and 4081.4 mm and thus, it is not acceptable for the analysis. The Weibull analysis method showed that the maximum probability of flooding in 5 years is 2156.1 mm, which corresponds to the mean rainfall value of 2149.1 mm, or about 95%. The results are consistent with those of the study conducted by Abd Rahman et al. (2022), showing that the Weibull method is the most consistent compared to the average maximum rainfall over 30 years, using positioning methods. The Weibull method represents a maximum rainfall that is about 95% of the average maximum for the rainfall. Another study (Sim et al., 2019) revealed that Chigodayev's technique presented the best fitting distribution of annual rainfall.

Table 5. Maximum annual rainfall (mm) based on plotting position methods for all stations

Method/Return Period	5 years (x) in mm	10 years (x) in mm	25 years (x) in mm	50 years (x) in mm	100 years (x) in mm
Weibull	**2156.1**	**2656.4**	**3270.9**	**3741.2**	**4221.5**
Hazen	2430.6	2901.1	3523.3	3993.9	4464.3
California	2247.6	2735.6	3380.5	3868.3	4356.2
Beard	2098.1	2577.6	3211.6	3691.1	4170.5
Chegodayev	2099.9	2580.4	3216.4	3696.5	4177
Blom	2086.7	2559.3	3184	3656.5	4129
Tukey	2107.9	2585.6	3217	3694.7	4172.4
Gringorten	2075.6	2539.5	3153.2	3617.3	4081.4
Cunnane	2081.4	2553.9	3178.2	3650.5	4122.9
Adamowski	2106.7	2594.2	3238.4	3725.8	4213.3
AVERAGE RAINFALL	**2149.1**	**2628.4**	**3257.4**	**3733.58**	**4210.85**

Potential Flood Frequency at Different Return Periods Using the Gumbel Maximum Value Distribution by Annual Rainfall

Flood frequency analysis is important, because it helps in understanding the nature and magnitude of floods, predicting floods, reducing flood damage, and designing hydraulic structures (Fischer & Schumann, 2021). It is also crucial for local and regional development planning and flood insurance (Meng et al., 2020). Flood frequency analysis provides information on the relationship between the magnitude of floods and their frequency of occurrence, allowing for the estimation of flood quantiles for different return periods (Breinl et al., 2021). This estimation is essential for making informed decisions regarding flood risk management and floodplain management. Different methods and distributions, such as Gumbel's extreme value distribution, power-law distribution, and various probability distribution functions, are used for flood frequency analysis (Apken et al., 2020). These methods and distributions help in accurately estimating flood flows, selecting appropriate truncation levels, and improving the prediction of floods.

Gumbel distribution has been applicable to analyze flood frequency in multiple studies (Islam & Sarkar, 2021; Lone et al., 2023; Manohar Reddy, 2022). Rainfall data collected from several sites was analyzed using probabilistic techniques (Amman Hussein College, Na'ur, Sweilih and Wadi Es-sir). By distributing the maximum annual precipitation using probabilistic methods for all stations. The Gumbel distribution was used to identify the best match with the real data, as shown in Table 6. The Pearson type-III distribution closely approximates the maximum precipitation, so that the result for rainfall during the probability of recurring floods over 100 years was respectively 2131, 2566.9, 3018.7, 3338.8, and 3649.5 mm, compared to the average based on positioning techniques for all stations of 2149.1, 2628.4, 3257.4, 3733.58, and 4210.85 mm. By comparing the analysis results using the positioning and probabilistic methods, it was found that there is a possibility of recurrence of the flood after 5 or 10 years, as shown in Table 7, while the rainfall amount was very close, so that through the plotting position methods 2149.1 mm and 2628.4 mm, and through the probabilistic methods it was 2131 mm and 2566.9 mm, respectively. Floods and heavy rainfall cause soil erosion and hence, further soil and sand stabilization is required in the affected areas (Bani Baker et al., 2022).

Table 6. Average maximum annual rainfall (mm) based on probabilistic methods for all stations

Distribution/Return Period	**5 years (x) in mm**	**10 years (x) in mm**	**25 years (x) in mm**	**50 years (x) in mm**	**100 years (x) in mm**
NORMAL	2211.6	2500.6	2808.5	3007	3186.7
GUMBEL	2115.6	2486.3	2954.4	3301.4	3646.7
PEARSON TYPE-III	**2131**	**2566.9**	**3018.7**	**3338.8**	**3649.5**
LOG-NORMAL	2126.4	2511.7	3003.6	3371.4	3742.5
LOG-PEARSON TYPE-III	2108	2468.4	2925.6	3271.7	3624.5

Table 7. Comparison of analysis results using the positioning and the probabilistic methods

Distribution/ Return Period	**5 years (x) in mm**	**10 years (x) in mm**	**25 years (x) in mm**	**50 years (x) in mm**	**100 years (x) in mm**
Plotting Position Methods	2149.1	2628.4	2357.4	3733.58	4210.85
Probabilistic Methods (PEARSON TYPE-III)	2131	2566.9	3018.7	3338.8	3649.5

Monthly-rainfall Analysis

Rainfall data is essential for the mathematical modeling of hydrological events, such as floods. Therefore, rainfall data is collected from different stations in order to aggregate data into a table. Mean and standard deviation were calculated in order to estimate the variation in rainfall. Chi-square values obtained are compared for all the methods and the least chi-square value in all cases is given by Gumbel distribution.

Table 8. Chi-square values for monthly rainfall analysis

Distribution	**Chi-square value (X^2)**	**P-value**
GUMBEL	$(10.0)^2 = 100$	0.0752
NORMAL	$(14.0)^2 = 196$	0.0156
PEARSON TYPE-III	**$(9.0)^2 = 81$**	**0.0611**
LOG-NORMAL	$(9.0)^2 = 81$	0.1091
LOG-PEARSON TYPE-III	$(10.5)^2 = 110.25$	0.0328

Compared to the study conducted by (Arvind et al., 2017) the results revealed that the Gumbel method estimation resulted in the lowest value of chi-square. However, the lowest P-value was 0.0611, which indicates the least variability rainfall amounts, so that Pearson type-III distribution delivers the most accurate representation of monthly rainfall data.

Statistical Parameters for Monthly Rainfall

It is observed from Table 9 that maximum average rainfall is received in December, January, February, and March during the winter, having standard deviation values of less than their corresponding mean values. In contrast, the standard deviation values for the remaining months are higher than their corresponding mean values, showing larger variation in the distribution of rainfall over the months. The statistics of monthly rainfall series data are positively skewed.

Table 9. Statistical parameters for monthly rainfall analysis

Month	Mean (mm)	Standard Deviation (mm)	Coefficient of Variation (Cv)	Coefficient of Skewness (Cs)
OCTOBER	9.26	14.10	1.52	2.88
NOVEMBER	36.80	41.51	1.13	1.58
DECEMBER	**83.79**	**76.73**	**0.92**	**1.54**
JANUARY	**111.93**	**61.07**	**0.55**	**0.23**
FEBRUARY	**97.38**	**73.83**	**0.76**	**2.02**
MARCH	**59.02**	**53.35**	**0.91**	**0.87**
APRIL	11.90	17.62	1.49	2.44
MAY	4.67	9.78	2.10	3.53

Seasonal-rainfall Analysis

The results in Table 10 indicate that the average annual rainfall during winter is 1410 mm. This figure is significant, as it suggests that winter is the dominant season for rainfall in the region, aligning with the general Mediterranean climate pattern, where the bulk of annual precipitation is concentrated in the cooler months. The standard deviation of 580 mm indicates substantial variability in winter rainfall from year to year. The CV of 0.412 suggests moderate variability relative to the mean. A CV-value closer to 0 would indicate more consistent rainfall, whereas a higher value would indicate greater unpredictability. The moderate CV observed here indicates that while there is variability, it is within a range that might be expected in a semi-arid to Mediterranean climate. The skewness value of 1.83 indicates a positively skewed distribution, meaning that extreme rainfall events (outliers) occur more frequently than low rainfall events. This skewness suggests that while most winters may have rainfall close to the mean, there are some winters with significantly higher rainfall, which could be associated with specific atmospheric conditions conducive to heavy precipitation evenys.

Table 10. Statistical parameters for winter rainfall analysis

Statistical Parameters	Winter
Mean (mm)	1410
Standard Deviation (mm)	580
Coefficient of Variation	0.412
Coefficient of Skewness	1.83

CONCLUSION

The comprehensive analysis of annual, monthly, and seasonal rainfall data from 1991 to 2022 across four stations within the study area has provided valuable insights into the rainfall patterns and potential flood risks. The application of various plotting position methods and probabilistic methods allowed for a robust estimation of maximum annual rainfall, highlighting the importance of selecting appropriate statistical techniques based on the context of the study. Among the methods analyzed, the Weibull method was found to be consistent with the mean maximum rainfall, reinforcing its reliability in flood risk assessment. Conversely, the Gringorten method consistently yielded lower values, indicating that it may not be suitable for this type of analysis.

The analysis of potential flood frequency using the Gumbel maximum value distribution demonstrated the necessity of accurate flood prediction for effective water resource management and infrastructure planning. The close alignment of results between the Gumbel distribution and the Pearson Type-III distribution suggests that these methods are well-suited for modeling extreme rainfall events in the region.

Seasonal analysis further confirmed that winter is the dominant season for rainfall, with significant variability from year to year, emphasizing the Mediterranean climate's influence on the region. The positive skewness in the rainfall distribution suggests that extreme rainfall events are relatively common, which could pose challenges for flood management and necessitate careful planning.

Overall, this study underscores the critical role of selecting appropriate statistical methods for rainfall and flood analysis to inform risk management strategies, infrastructure design, and regional planning. The results also highlight the need for continued monitoring and analysis to adapt to potential changes in rainfall patterns due to climate variability or other factors.

REFERENCES

Abdelkarim, A., and Gaber, A.F.D. (2019). “Flood risk assessment of the Wadi Nu’man basin, Mecca, Saudi Arabia (during the period, 1988-2019) based on the integration of geomatics and hydraulic modeling: a case study”. Water, 11 (9), 1887. https://doi.org/10.3390/w11091887

Abd Rahman, N.F., Hisham, N., Mohammad, M., Tai, V.C., Khalid, K., and Mohmad Sharif, M. S. (2022). “Statistical analysis of 30-year rainfall data: A case study for langat river basin”. Eurasia Proceedings of Science, Technology, Engineering and Mathematics, 21. https://doi.org/10.55549/epstem.1226646

Abdulrazzak, M., Elfeki, A., Kamis, A., Kassab, M., Alamri, N., Chaabani, A., and Noor, K. (2019). "Flash flood risk assessment in urban arid environment: Case study of Taibah and Islamic Unniversities’ campuses, Medina, Kingdom of Saudi Arabia". Geomatics, Natural Hazards and Risk, 10 (1), 780-796. https://doi.org/10.1080/19475705.2018.1545705

Adlouni, S. El, and Bobée, B. (2011). "Decision support system for flood risk assessment". Flood Engineering, 2 (1), 11-26.

Al Daraien, R., and Al Atawneh, D. (2021). “Time series analysis of rainfall variability at north Jordan: A case study at Yarmouk river basin". IOP Conference Series: Earth and Environmental Science, 775 (1). https://doi.org/10.1088/1755-1315/775/1/012001

Alhasanat, H.A. (2017). “Early warning system guidance to mitigate flash flood impacts in Petra region, Jordan. http://usir.salford.ac.uk/44382/1/SalfordUniversity Final PhD Thesis Hussein Alhasanat November 2017.pdf

Al-Saeedi, B.A., Baez-Villanueva, O.M., and Ribbe, L. (2024). “An optimized representation of precipitation in Jordan: Merging gridded precipitation products and ground-based measurements using machine learning and geostatistical approaches". https://doi.org/10.5194/EGUSPHERE-EGU24-11510

Al Saodi, R., Al Kuisi, M., and Al Salaymeh, A. (2023). “Assessing the vulnerability of flash floods to climate change in arid zones: Amman-Zarqa basin, Jordan". Journal of Water and Climate Change, 14 (12), 4376-4403. https://doi.org/10.2166/wcc.2023.237

Al-Sheriadeh, M., and Al-Sharman, A.R. (2024). “Evaluation of satellite rainfall estimates using PERSIANN-CDR and TRMM over three critical cells in Jordan". Journal of Hydroinformatics, 26 (2), 424-440. https://doi.org/10.2166/HYDRO.2024.154

Apurv, T., Mehrotra, R., Sharma, A., Goyal, M.K., and Dutta, S. (2015). “Impact of climate change on floods in the Brahmaputra basin using CMIP5 decadal predictions". Journal of Hydrology, 527, 281-291. https://doi.org/10.1016/j.jhydrol.2015.04.056

Arabeyyat, O., Shatnawi, S., and Matouq, M. (2018). “Nonlinear multi-variate rainfall prediction in Jordan using NARX-ANN model with GIS techniques". Jordan Journal of Civil Engineering, 12 (3).

Armon, M., Morin, E., and Enzel, Y. (2019). “Overview of modern atmospheric patterns controlling rainfall and floods into the Dead Sea: Implications for the lake’s sedimentology and paleohydrology". Quaternary Science Reviews, 216, 58-73. https://doi.org/10.1016/j.quascirev.2019.06.005

Arvind, G., Ashok Kumar, P., Girish Karthi, S., and Suribabu, C.R. (2017). “Statistical analysis of 30-year rainfall data: A case study". IOP Conference Series: Earth and Environmental Science, 80 (1). https://doi.org/10.1088/1755-1315/80/1/012067

Bani Baker, M., Abendeh, R., Sharo, A., and Hanna, A. (2022). “Stabilization of sandy soils by bentonite clay slurry at laboratory bench and pilot scales". Coatings, 12 (12). https://doi.org/10.3390/coatings12121922

Darwin Kombaitan, B., Yudoko, G., and Purboyo, H. (2018). “Application of GIS on determination of flood prone areas and critical arterial road network by using Chaid method in Bandung area". MATEC Web of Conferences, 147. https://doi.org/10.1051/matecconf/201814702007

Ghumaid, A. (2023). “Studying he change in hydrological conditions for the Amman-Zraqa basin using incremental climate change scenarios, a soil and water assessment model, and geospatial techniques". An-Najah University Journal for Research-B (Humanities), 37 (5), 943-980. https://doi.org/ 10.35552/0247.37.5.2011

Gumble, E.J. (1941). “The return period of flood flows". The Annals of Mathematical Statistics, 12 (2), 163-190.

Hoffmann, P. (2023). “A contextualization of heavy rainfall events in climate forecasts: A case study for Amman in Jordan". https://doi.org/10.5194/EMS2023-554

Kareem Jebur, Ahmed. (2021). “Uses and applications of geographic information systems". Saudi Journal of Civil Engineering, 5 (2), 18-25. https://doi.org/10.36348/sjce.2021.v05i02.001

Lone, S.A., Sindhu, T.N., Hassan, M.K.H., Abushal, T.A., Anwar, S., and Shafiq, A. (2023). “Theoretical structure and applications of a newly enhanced Gumbel type-II model". Mathematics, 11 (8). https://doi.org/10.3390/math11081797

Loudyi, D., and Kantoush, S.A. (2020). “Flood risk management in the Middle East and North Africa (MENA) region". Urban Water Journal, 17 (5), 379-380. https://doi.org/10.1080/1573062X.2020.1777754

Mohita Anand, S., and Jai Bhagwan, S. (2010). “Use of probability distribution in rainfall analysis". New York Science Journal, 3 (9), 40-49.

Odeh, T., Mohammad, A.H., Pradhanang, S.M., Ismail, M., and Rödiger, T. (2022). “GIS-based analytical modeling on evaluating impacts of urbanization in Amman water resources, Jordan". Environmental Earth Sciences, 81 (5), 1-15. https://doi.org/10.1007/S12665-022-10238-7/METRICS

Osei, M.A., Amekudzi, L.K., Omari-Sasu, A.Y., Yamba, E.I., Quansah, E., Aryee, J.N.A., and Preko, K. (2021). “Estimation of the return periods of maximum rainfall and floods at the Pra river catchment, Ghana, West Africa using the Gumbel extreme value theory". Heliyon, 7 (5), e06980. https://doi.org/10.1016/j.heliyon.2021.e06980

Parkash, S.I.B.R. (2014). “Activity book of national institute of disaster management: Disaster management for school students". National Institute of Disaster Management (Vol. 110016). https://nidm.gov.in/PDF/pubs/ACTIVITYBOOK DM.pdf

Rad, S., Junfeng, D., Jingxuan, X., Zitao, L., Linyan, P., Wan, Z., and Lin, L. (2022). “Lijiang flood characteristics and implication of karst storage through Muskingum flood routing *via* HEC-HMS, S. China". Hydrology Research, 53 (12), 1480-1493. https://doi.org/10.2166/nh.2022.060

Sayers, P., Galloway, G., Penning-rowsell, E., Shen, F., Kang, W., Yiwei, C., and Le Quesne, T. (2013). “Flood risk management: A strategic approach". In: UNESCO. https://bit.ly/2TkeZHz

Sayers, P., Li, Y., Galloway, G.G.G.G.G., Penning-Rowsell, E.E.E.E., Shen, F., Quesne, T. Le, Fuxin, S., Yiwei, C., Kang, W., and Yuanyuan, L. (2013). “Flood risk management: A strategic approach - Part of a series on strategic water management". In: Water and Sewerage Journal. http://unesdoc.unesco.org/images/0022/002208/220870e.pdf

Shammout, M.W. (2023). “Calculation and management of water supply and demand under land use/cover changes in the Yarmouk river basin in Jordan". Land, 12 (8). https://doi.org/10.3390/land12081518

Sim, I., Lee, O., Jeong, S., and Kim, S. (2019). “Estimating the return period for statistical probable maximum precipitation". Journal of the Korean Society of Hazard Mitigation, 19 (1). https://doi.org/10.9798/kosham.2019.19.1.373

Sun, P., Wen, Q., Zhang, Q., Singh, V. P., Sun, Y., and Li, J. (2018). “Non-stationarity-based evaluation of flood frequency and flood risk in the Huai river basin, China". Journal of Hydrology, 567, 393-404. https://doi.org/10.1016/j.jhydrol.2018.10.031

Towfiqul Islam, A.R.M., Talukdar, S., Mahato, S., Kundu, S., Eibek, K.U., Pham, Q.B., Kuriqi, A., and Linh, N.T.T. (2021). “Flood susceptibility modeling using advanced ensemble machine learning models". Geoscience Frontiers, 12 (3). https://doi.org/10.1016/j.gsf.2020.09.006