DOI: 10.4408/IJEGE.2020-01.O-02

EXTREME FLOODS IN CENTRAL JORDAN: FREQUENCY ANALYSIS

ZEYAD TARAWNEH[(*)], NIDAL HADADIN[(**)] & ESRAA TARAWNEH[(***)]

[(*)]Department of Civil Engineering, Hashemite University, 13115 Zarqa, Jordan
[(**)]Department of Civil Engineering, The University of Jordan, 11942Amman, Jordan
[(***)]Department of Civil Engineering, Mutah University, 61710Mutah, Jordan
Corresponding author: zeyadt@hu.edu.jo

EXTENDED ABSTRACT

Negli ultimi anni, la Giordania e altri Paesi del Medio Oriente sono stati interessati da inondazioni distruttive, con perdite di vite umane e danni alle infrastrutture. Questo studio analizza le inondazioni improvvise giornaliere nella regione del Wala, nella Giordania centrale, dove si è verificata la maggior parte delle alluvioni, come quella tragica del 10 Novembre 2018. Per quantificare l'entità, la distribuzione della durata del flusso e la frequenza delle alluvioni, sono stati utilizzati i flussi giornalieri osservati, quelli sintetici e sviluppati modelli teorici. Sono state quindi suggerite misure per ridurre l'impatto delle future alluvioni nel bacino del Wala, l'area oggetto di studio, situato a monte della diga di Wala di estensione pari a 1743 km^2. L'area nel periodo invernale riceve una precipitazione media di 226mm, dove il deflusso superficiale generato a monte del bacino viene utilizzato per ricaricare le falde acquifere e fornire acqua per l'irrigazione alle attività agricole a valle della diga. Il bacino del Wala ha una pendenza media del 3,8%, una lunghezza del corso principale di 80,9 km e una CN media di 70, con un tempo di ritardo e un tempo di concentrazione calcolato nel bacino, rispettivamente pari a 18,9 ore e 31,5 ore, e l'idrogramma unitario SCS a 1ora indica un tempo di base dell'idrogramma pari a 52 ore, che potrebbe giustificare l'uso di flussi giornalieri per caratterizzare inondazioni estreme. Lo studio ha utilizzato dati giornalieri di flusso intermittente, del periodo ottobre 2002-agosto 2016, come base per generare una serie molto lunga di flussi giornalieri sintetici, che possono essere utilizzati per analizzare e rilevare inondazioni estreme giornaliere, non evidenziate dall'analisi dei flussi brevi osservati. A tal fine, è stato inizialmente ottenuto il processo di non occorrenza (stato 0) e di occorrenza (stato 1) dei flussi giornalieri ed il processo 0-1 è stato assunto come due stati stazionari semplici di Markov, mentre l'entità del flusso giornaliero è stata modellata utilizzando una distribuzione Gamma a due parametri. Le probabilità di stato condizionato e incondizionato stimate sono state P0=0,935, P00 = 0,971 e P11 = 0,598 e gli stimatori della distribuzione Gamma e dei parametri di forma e scala, rispettivamente pari a α = 0,281 e λ = 0,443. La distribuzione Gamma a due parametri dedotta, ben si adatta alla distribuzione dei flussi giornalieri del Wala, specialmente per la coda superiore dei flussi. Usando le probabilità dello stato condizionale ed incondizionato e la distribuzione Gamma è stata generata una serie molto lunga di flussi giornalieri sintetici (100 volte più lunghi del record di flusso giornaliero osservato). È risultato che i flussi giornalieri sintetici ben rappresentano i flussi osservati pertanto sono stati utilizzati per individuare il verificarsi di alluvioni estreme non rilevate utilizzando i brevi flussi giornalieri osservati. L'analisi dei flussi giornalieri sintetici osservati, con i modelli teorici sviluppati, ha mostrato che circa il 40% dei flussi giornalieri sono da riferirsi ad eventi di un giorno e circa il 24% ad eventi di 2 giorni. Tali inondazioni di breve durata (64% del tempo) sono comuni nei mesi di Novembre e Dicembre, nel passaggio dalla stagione delle piogge a quella non piovosa e hanno seguito il modello delle brevi tempeste invernali, prevalentemente di 2 giorni o meno, nella regione della Giordania centrale. L'analisi delle lunghe serie di flussi sintetici ha mostrato la possibilità di insorgenza di numerose alluvioni estreme di magnitudo superiori alla più grande alluvione osservata (10.368 milioni di m^3/giorno), pari a 14,65 milioni di m^3/giorno. Il tempo di ritorno calcolato e la probabilità di occorrenza della più grande inondazione osservata sono stati rispettivamente di 78 anni e dell'1,3%. Questa può essere considerata come un evento raro poiché la regione del Wala è soggetta a inondazioni di magnitudo pari o inferiori a 6,337 milioni di m^3/giorno. Per mitigare l'effetto di possibili alluvioni improvvise, il rimboschimento del bacino del Wala a monte della diga con un adeguato schema di contro terrazzamento potrebbero essere pratiche adeguate ad attenuare l'entità delle future alluvioni.

.

ABSTRACT

This research aims at analyzing the frequency and duration distribution of extreme floods, including flash, in the Wala catchment - Central Jordan. The observed daily flows series, October 2002 to August 2016, was short to characterize extreme events like the 10th of November 2018 deadly flash flood. Therefore, a very long series of intermittent daily flows was synthesized assuming that the daily flow-nonflow process is stationary two-state simple Markov and the daily flow magnitude is Gamma distributed.

The synthesized flows have succeeded to copy the characteristics of the observed flows. The analysis of the Wala observed, simulated daily flows and results from the theoretical model showed that floods of duration 2 days or less were dominant events (64%); the single day type was more often (40%) compared to the 2 days flood (24%). Regarding the 10th of November 2018 deadly flash flood of 10.368MCM/day, the inspection of the synthesized daily flows showed that it was an uncommon incident of 78 years recurrence time.

Afforestation the upper regions in the Wala catchment and construction of counter terracing are possible measures to mitigate the impact of future flash floods.

KEYWORDS: *flash floods, frequency analysis, intermittent flow, Jordan*

INTRODUCTION

Extreme floods, of recurrence time and peak magnitude, are the first among the natural calamities in the world (GAVARDASHVILI, 2013). During the 2018/2019 rainy season, Jordan has witnessed three major floods; two were classified as the worst deadly flash floods over several decades.

These floods left Jordan with several human deaths and injuries, substantial damage to the infrastructure and economic losses due to flooded commercial regions in Amman and other Jordanian cities. Although Jordanian lands receives low to moderate annual rainfalls over the whole rainy season, around 100mm or less in southern and eastern regions to around 600 mm in the north-west regions; however, sometimes the country witnesses heavy rainfall events that usually cause devastating flash floods.

In small basins, such short time intense rainfalls usually generate extreme floods (KUNDZEWICZ *et alii*, 2014). The intense rainy storms in Jordan regularly occur during the transition period between seasons, October – November for non rainy to rainy, while March – May for rainy to non rainy (AL-QUDAH, 2011). Normally, the rainy season in Jordan begins effectively in the beginning of November and ends in the mid of April (Fig. 1).

Recently and over the past few decades, Jordan has faced several devasting flash floods that have ended with considerable damage to the infrastructure including historical

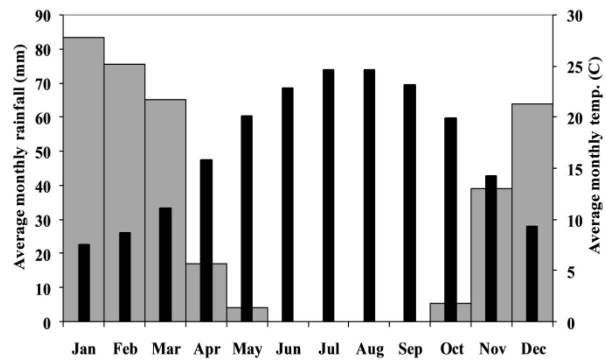

Fig. 1 - Average monthly rainfall in mm (grey bars) and temperature in ℃ (black bars) for Madaba region - Central Jordan

Fig. 2 - The Roman theatre in Amman after the 28th of February 2019 flash flood

sites (Fig. 2), commercial losses and human casualties.

Table 1 shows a summary of recent and historic flash floods in Jordan. In literature, few studies about floods in Jordan were conducted concentrating either on estimating the magnitude of the flood peak and suggesting measures to reduce its impact on human activities (AL-WESHAH & EL-KHOURY, 1999; AL-QUDAH, 2011) or mapping the susceptibility of extreme floods in some of the Jordanian arid regions (FARHAN & AYED, 2017). Previous flood studies in Jordan have used rainfall-runoff computer models (HEC-1, HEC-RAS and GIS) to simulate and generate flood peaks given the study region characteristics and rainfall data from gauging stations within and around the studied regions.

For accuracy purposes, such computer models need information of high quality to properly calibrate, validate, generate floods and determine peak values. Although previous flood studies in Jordan are significant; however, few short comings were reported. AL-WESHAH & EL-KHOURY (1999) reported a non continuous daily rainfall data for parts of the study period (1980 up to 1995) and few observed peak flows from limited number of storms in Petra region.

Date (Location)	Damage due to the flash flood	Notes
28/2/2019 (Amman)	2000 accidents: houses flooding, vehicles being swept away and 279 downtown traders affected by the flood. Estimated damage cost = 15 Million $	Heavy rainfall: 68mm in 24hours (nearly 20% of the whole rainy season).
10/11/2018 (Madaba and Petra)	12 people were killed and 29 were injured in Wala region, Madaba. Evacuation of thousands of tourists from the ancient city of Petra	Flash flood of 10.368 MCM /day**.
25/10/2018 (Zara)	21 school children were killed and several injured in Zara region near the Dead Sea	Heavy rainfall: 50mm in 20minutes.
11/3/1966 (Ma'an)	100 people were killed in Ma'an city	Heavy rainfall in the desert area of Ma'an.

*Tab. 1 - Recent and historic flash floods in Jordan. **MCM: Million Cubic Meters.*

Furthermore, the quality of rainfall data from gauging stations in Southern Jordan was dubious due to the poor control and the existence of missing data (Al-Qudah, 2011). In general, information from conventional rain-gauge networks may not well capture the severity of storms that generate flash floods (Koutroulis & Tsanis, 2010).

In literature different procedures were used to estimate or model the flood peak. These procedures rely on either empirical equations (e.g. Koutroulis & Tsanis, 2010; Alabyan, 2018), standard hydrological models (e.g. Chandramohan & Vijaya, 2017), runoff generation computer models and neural networks (e.g. Kisi *et alii*, 2013; Shabanlou, 2014), paleofloods (e.g. Lopez-Aviles, 2007), or stochastic models (e.g. Todorovic & Zelenhasic, 1970; Georgakakos, 1986; Morrison & Smith, 2002; Tsakiris *et alii*, 2015).

In the direct flood frequency analysis with observed peakflow as an input data, all procedures were involved in selecting and fitting an appropriate theoretical probability distribution to model the flood frequency (Smithers, 2012). For example, the generalized extreme value (GEV) distribution was used to model the peak floods considering either the annual maximum series or the partial duration series of peakflows (Morrison & Smith, 2002; Villarini *et alii*, 2012; Vivekanandan, 2014).

Other distributions like the four-parameter kappa, three-parameter generalized Pareto and lognormal distributions were found to provide a good approximation to flow duration curves (Blum *et alii*, 2017). The major objective of this research is to model and characterize extreme floods, including flash floods, of the Wala region in central Jordan where the majority of recent flash floods have happened. The characterization involves the determination of the flood duration distribution and how frequent the deadly 10th of November 2018 flash flood is. Furthermore, this study will suggest few measures to reduce the impact of future flash floods in the Wala catchment.

MATERIALS AND METHODS

The Wala catchment upstream the Wala dam (Fig. 3) is selected as a study region to characterize flash floods in central Jordan where recent deadly floods have occurred (Table 1). Upstream the Wala Dam (31° 34' 5.4"N, 35° 48' 16.6"E), the catchment area is 1743 km^2. The Wala Dam of the 9MCM storage capacity, located 60 km south of Amman, was constructed between 1999 and 2002 to harvest the surface runoff during the rainy season. The dam storage is used mainly to recharge the ground aquifers and provide irrigation water to all downstream agricultural activities (Tarawneh *et alii*, 2016). In general, the study region is characterized by hot dry climate during the summer while cool cold wet climate during the winter. It receives an average precipitation of 226 mm during the rainy season.

The Wala catchment has an average slope of 3.8%, streamflow length of 80.9 km and an average CN (Curve Number) of 70. Based on the SCS (Soil Conservation Service) methodology, the computed catchment lag time and time of concentration are 18.9hrs and 31.5hrs, respectively. Furthermore, the computed 1hr SCS unit hydrograph for the Wala catchment indicates a hydrograph base time of 52hrs which could justify the use of daily flows to characterize extreme floods.

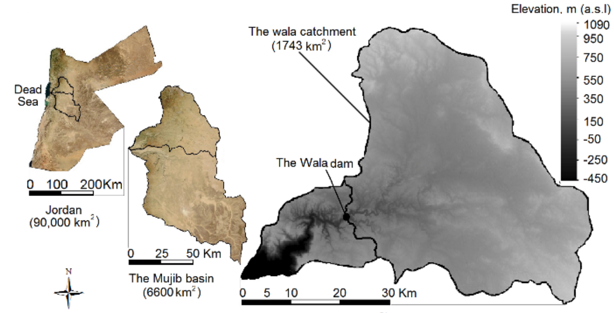

Fig. 3 - The Wala catchment in Central Jordan (Tarawneh et alii,2016)

This study uses daily observed flow data covering the period from 30 October 2002 to 2 August 2016 to characterize extreme daily floods. The 0 flow data over the non rainy season, mid of April to the end of October (Fig. 1), has been removed because there are no storms during the summer. During the rainy season, beginning of November to the mid of April (Fig. 1), daily flows run in the Wala valley throughout the existence of the rainy storm, and somehow after depending on the catchment characteristics, and return to 0 right after the storm effect vanishes. Therefore, during the rainy season, the Wala daily flows series forms an intermittent series of 5025 observed flows measured at the dam site. Figure 4 shows the intermittent series of the observed daily flow spanning over the study period.

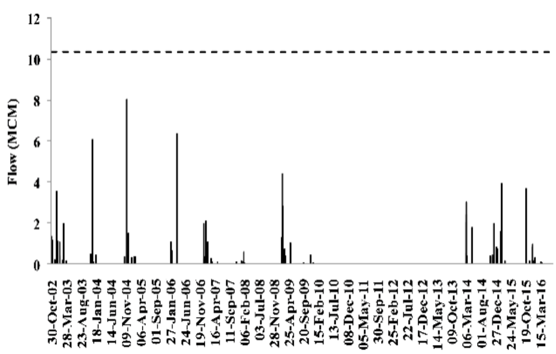

Fig. 4 - The Wala valley intermittent observed daily flow (bars). The Dashed line represents the 10th of November 2018 flash flood of 10.368MCM/day measured at the Wala dam site.

In order to figure out how frequent was the 10th of November 2018 flood of magnitude 10.368MCM/day, the general procedures described in AKSOY& BAYAZIT (2000) and AKSOY (2003) will be used to synthesize the Wala intermittent daily flows under the assumption that the occurrence and the non occurrence of the daily flow is stationary two-state simple Markov process. In Jordan, so far there is no scientific evidence that climate change has changed the pattern of the surface flow or the magnitude of the flood; therefore, the modeling of the daily flow as stationary process looks plausible.

For daily flow generation, at first the intermittent daily flow series is converted to a 0 – 1 process, the state 1 is assigned to the flow occurrence and 0 otherwise. Having estimates of the unconditional and conditional state probabilities (P_i, P_{ii} and P_{jj}) a synthetic 0 – 1 process (Y) to simulate the daily flow occurrence and non occurrence is generated as follows:

1 – A random number (U_1) is generated from the Uniform distribution, $U \in [0, 1]$.

2 – If $U_1 \leq P_i$, then the initial seed is the state i, otherwise j.

3 – Assuming the initial seed takes the state i, i.e. $Y_1 = i$, then the state of Y_{t+1} is:

$$Y_{t+1} = \begin{bmatrix} i, as\ long\ as\ U_t \leq P_{ii} \\ j, otherwise \end{bmatrix}, t=1,2,\ldots \qquad (1)$$

where Ut is a new random number generated at the time (t) as in step 1.

The state j continues to occur as long as $U \leq P_{jj}$, otherwise returns to i. Notations in steps 2 and 3 are inverted if the initial state is j. After generating the 0 – 1 process, the two-parameter Gamma distribution is used to directly generate the magnitude of the daily flow. The probability density function of the two-parameter Gamma is:

$$f(x) = \frac{\lambda^{\alpha} x^{\alpha-1} e^{-\lambda x}}{\Gamma(\alpha)} \qquad (2)$$

where x is the flow magnitude (an independent variable), α and λ are the distribution shape and scale parameters, respectively. In AKSOY &BAYAZIT (2000) and AKSOY (2003), the Gamma distribution was used to generate the flow increments over the rising limb of the hydrograph, while the flow decrements was calculated given the exponential recession of the falling limb of the hydrograph. For the Wala catchment, the majority of the observed daily flows generated due to time separated short duration storms (1 - 2 days at most).

Unfortunately, it was hard to obtain the complete components of the flow hydrograph, i.e. clear rising and falling limbs of the complete hydrograph were not utilized most of the time. For that reason, the Wala catchment daily flow magnitude is assumed Gamma independent random variable. After generating a new random number (U_f) from the uniform distribution, the magnitude of the daily flow (x) is computed from the Gamma distribution cumulative probability, $P(X \leq x)$, such that $P(X \leq x) = U_f$. Theoretically, the distribution of the flow duration (d) is computed as:

$$P[D = d] = P[Y_d = 1, Y_{d-1} = 1,.., Y_1 = 1 | Y_0 = 0] \qquad (3)$$

Since the daily flow is assumed stationary two states simple Markov process then Eq.(3) is reduced to $P[Y_d = 1, Y_{d-1} = 1, \ldots.., Y_2 = 1] \times P[Y_1 = 1 | Y_0 = 0]$. The term $P[Y_1 = 1 | Y_0 = 0] = P01$, *and the term* $P[Y_d = 1, Y_{d-1} = 1, \ldots.., Y_2 = 1]$ is reduced to $P[Y_t = 1 | Y_{t-1} = 1]^{(d-1)} = P_{11}^{(d-1)}$. Therefore, the probability distribution function of the flow duration is:

$$P[D = d] = P_{01} \times P_{11}^{d-1} \qquad (4)$$

For flash flood characterization, i.e. how frequent the event is, the return period *(T)* defined as the expected value of the waiting time *(w)* between successive flood events that exceed a specified value is computed as:

$$T = E(W) = \frac{w_1 + w_2 + \cdots + w_n}{n} \cong \frac{L}{n} \quad (5)$$

where n is total the number of flood events and *L* is the length of data used to characterize floods. For the intermittent daily flow series, it can be argued that flow events of magnitude exceed a specified value are independent flood events especially when the daily flows are surface runoffs due to time separated rainy storms given that the baseflow is absent. For continuous river flows, independence among seasonal floods was assumed in previous studies (e.g. BARATTI *et alii*, 2012). Under the assumption that floods events due to time separated storms emerge independently, the occurrence probability of observing a flood event equals or exceeds the specified value *(x)* is:

$$P(X > x) = \frac{1}{T} \quad (6)$$

RESULTS AND DISCUSSION

In order to characterize extreme floods in the Wala region, and since the observed flow data provided limited information about extreme past floods (few historical extreme flood events existed), the stochastic nature of the intermittent Wala daily flow was used to generate a synthetic series of daily flows. Based on the 5025 observed daily flows, the estimates of the unconditional and the conditional state probabilities were $P0$ = 0.935, $P00$ = 0.971 and $P11$ = 0.598, respectively, (the state 0 for non flow). Also, the moment estimators of the Gamma distribution shape and scale parameters were α = 0.281 and λ = 0.443, respectively. The series of the 5025 observed daily flows used to estimate the unconditional and the conditional state probabilities and the two state Gamma parameters could be quite long enough to obtain reliable estimates.

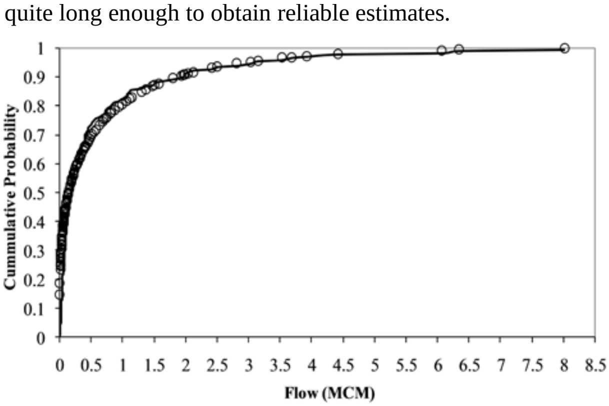

Fig. 5 - The fitted two-parameter Gamma distribution (solid curve) versus the empirical distribution of the daily flow (circles)

The visual inspection of how the two-parameter Gamma distribution well fitted the flow magnitude is illustrated in Fig. 5.

With the exception of the very low flows, the two-parameter Gamma distribution well fitted the distribution of the Wala daily flows especially for the upper tailof flows which is the case of this study (extreme floods). In general, distributions that allocate sufficient probability to the upper tail of flows must be employed (BOWERS *et alii*, 2012). Given the unconditional, the conditional state probabilities and the Gamma distribution parameters listed above and following the procedures mentioned in the previous section, the Wala synthetic daily flow series of sufficient length (100 times the length of the observed data) was obtained. The mean, the variance and the skewness of the synthetic daily flows were: 0.62, 1.43 and 3.88, respectively, which are very comparable to the Wala observed daily flows mean of 0.63, variance of 1.43 and skewness of 3.50; therefore, it can be concluded that the synthetic daily flows well copied the characteristics of the observed flow of the Wala catchment and can be used to capture extreme floods cannot be detected throughout the analysis of the short observed flows.

Upon inspecting the observed daily flow series of the Wala catchment (Fig. 4), the highest flow (historical flood) was a single day event of 8.013MCM magnitude which occurred in the 23th of November 2004. Figure 6 shows the flow (flood) duration distribution after analyzing the observed, synthetic flows and Equation 4.

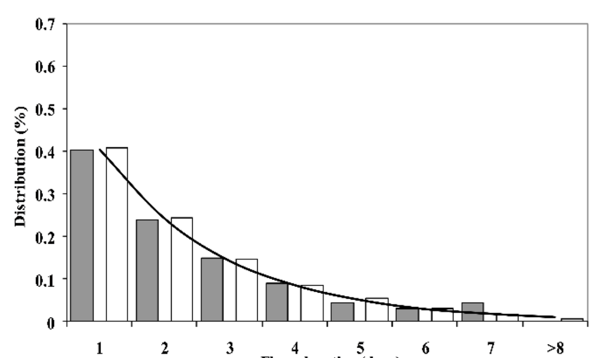

Fig. 6 - The distribution of the Wala daily flow (flood) versus the duration after analyzing observed flows (grey bars), synthetic flows (white bars) and using Eq.4 (solid curve)

In fact, due to the time separated rainy storms, the majority of the daily flows occurred in the Wala catchment were single day events of magnitude between 0.004 to 8.013MCM. After analyzing the observed daily flows, it has been found that about 40% of the daily flows (floods) were single day events, including the highest (8.013MCM) and the third highest (6.071MCM) floods occurred in the 23th of

November 2004 and the 16th of December 2003, respectively, and about 24% of events were 2 days floods (Fig. 6). In general, 64% of flow (flood) events were of 2 days duration or less, the single day events were common occurring mostly in November and December, i.e. during the shift from the rainy to the non rainy season. The same conclusion about the flow (flood) duration distribution has been found after analyzing the long series of synthetic flows and using the theoretical modeling, i.e Equation 4.

In general, the past daily flows generated in the Wala catchment followed the pattern of winter storms in which the region of central Jordan has experienced (mostly storms of 2 days or less).

The analysis of the long synthetic flows series showed the possible occurrence of several extreme flood events of magnitude much larger than the devastating 10th of November 2018 flash flood of 10.368MCM/day. The largest possible extreme flood from the analysis of the Wala simulated daily flows has the magnitude of 14.65MCM/day. After the analysis of the simulated flows, table 2 shows the return period and the occurrence probability, computed using Equations 5 and 6, respectively, for floods that exceed the four largest historical floods in the Wala region.

Flood date	Flood magnitude (MCM/day) ≥	Computed return period (years)	Computed occurrence probability
10/11/2018	10.368	77.8	0.013
23/11/2004	8.013	24.6	0.041
03/04/2006	6.337	10.6	0.094
16/12/2003	6.071	9.1	0.110

Tab. 2 - Return period and occurrence probability of floods in the Walacatchment computed using the simulated daily flows.

On average, the 10th of November 2018 devastating flash flood of magnitude 10.368MCM/day, or more, occurs once every 78 years with probability of 1.3%. Therefore, it can be concluded that such flash flood is a rare event in the Wala region.

In general, about 90% of time the Wala region is subjected to floods of magnitude of 6.337MCM/day or less.

Throughout the 2018/2019 rainy season, the Wala dam downstream the Wala catchment (Fig. 3) was over flooded 5 times. Currently, there are reconstructions to enlarge the dam storage capacity from 9MCM to about 26MCM to capture the most of winter floods for water supply enhancement. However, the 10th of November 2018 devastating flash flood has occurred in the upstream region of the Wala catchment due to short time intense rainfall storm. To mitigate the effect of possible future flash floods in the Wala catchment, this study recommends the application of afforestation combined with proper counter terracing scheme. The majority of sub-basins upstream the Wala catchment can be planted with proper type of trees (Olive treesare good candidates) that best fit the region climate. Besides the socio-economic aspects of planting olive trees and the conservation of soil due to an appropriate terracing, planting the upper sub-basins of the Wala catchment will affect the rainfall-runoff process causing substantial reduction in the peak magnitude of the flash flood.The combined effect of the increased infiltrated water and the increased sub-basins time of concentration, due to the plant interception and slope reduction, will attenuate the peakflow during flash floods. Al-Weshah &El-Khoury (1999) has reported a reduction of 27 – 50% in the flood peakflow in Petra region due to afforestation scenario only, while a reduction of 50 – 80% was achieved when afforestation is combined with proper terracing.

CONCLUSIONS

The analysis of the Wala catchment observed, synthetic daily flows and results from the theoretical model indicated that 64% of floods, including extremes, were short duration events distributed as 40% and 24% for the single day and two days events, respectively. The majority of the short duration extreme floods occurred usually in the beginning of the rainy season, i.e. the months of November and December, due to time separated rainy storms. It has been found that the two-parameter Gamma distribution well fitted the distribution of the Wala daily flows especially for extreme (upper tail) flows which is the case of this study. Modeling of the Wala intermittent daily flows by a stationary two-state simple Markov process combined with two-parameter Gamma distribution for the flow magnitude has successfully simulated and copied the characteristics of the observed daily flow, consequently, enabled the computation of how frequent was the devastating the 10th of November 2018 flash flood. The analysis showed that flash floods equal or exceed 10.368MCM/day were rare events happened once every 78 years with 1.3% probability. To mitigate the effect of future flash floods, this study recommends the application of proper afforestation combined with counter terracing scheme in the upper regions in the Wala catchment. Such mitigation measures enhance the infiltration process and increase the catchment time of concentration, consequently, the flash flood peakflow will be attenuated.

REFERENCES

Alabyan A., Belikov V., Krylenko I., Fingert E. & Fedorova T. (2018) - *Retrospective Simulation of an Extreme Flood on the Oka River at the City of Ryazan and Impact Assessment of Urban and Transport Infrastructure*. Water Resources, **45** (Supp. 1): 1-10.

AL-WESHAH R. & EL-KHOURY F. (1999) - *Flood analysis and mitigation for Petra area in Jordan*. Journal of Water Resources Planning and Management, **125** (3): 170-177.

AL-QUDAH K. (2011) - *Floods as water resource and as a hazard in arid regions: a case study in southern Jordan*. Jordan Journal of Civil Engineering, **5** (1): 148-161.

AKSOY H. & BAYAZIT M. (2000) - *A model for daily flows of intermittent streams*. Hydrological Processes, **14** (10): 1725-1744.

AKSOY H. (2003) - *Markov chain-based modeling techniques for stochastic generation of daily intermittent streamflows*. Advances in Water Resources, **26** (6): 663-671.

BARATTI E., MONTANARI A., CASTELLARIN A., SALINASJ., VIGLIONE A. & BEZZI A. (2012) - *Estimating the flood frequency distribution at seasonal and annual time scales*. Hydrology and Earth System sciences, **16**: 4651-4660.

BLUM A., ARCHFIELD S. & VOGEL R. (2017) - *On the probability distribution of daily streamflow in the United States*. Hydrology and Earth System sciences, **21:** 3093-3103.

BOWERS M., TUNG W. & GAO J. (2012) - *On the distributions of seasonal river flows: Lognormal or power law?*Water Resources Research, **48** (W05536): 1-12.

CHANDRAMOHAN K. & VIJAYA R. (2017) - *Hydrologic Computations of SCS-CN, Rational, Area velocity and Tc Methods for Quantifying the Forest Surface Water Runoff - A case study in Sirumalai hill environs of Sathiyar Reservoir, Madurai, Tamil Nadu, India*. International Research Journal of Engineering and Technology, **4** (4): 662-670.

FARHAN Y. & AYED A. (2017) - *Assessment of flash-flood hazard in arid watersheds of Jordan*. Journal of Geographic information System, **9**: 717-751.

GAVARDASHVILI G. (2013) - *Prediction of flooded territories in case of possible breakdown of the Sioni earth dam*. Italian Journal of Engineering Geology and Environment, Book series, **6**: 417-423. DOI: 10.4408/IJEGE.2013-06.B-40

GEORGAKAKOS K. (1986) - *A generalized stochastic hydrometeorological model for flood and flash flood forecasting: 1. Formulation*. Water Resources Research, **22** (13): 2083-2095.

KISI O., SHIRI J. & TOMBUL M. (2013) - *Modeling rainfall-runoff process using soft computing techniques*. Computers & Geosciences, **51**: 108-117.

KOUTROULIS A. & TSANIS I. (2010) - *A method for estimating flash flood peak discharge in a poorly gauged basin: Case study for the 13–14 January 1994 flood, Giofiros basin, Crete, Greece*. Journal of Hydrology, **385**: 150-164.

KUNDZEWICZ Z., KANAE S., SENEVIRATNE S., HANDMER J., NICHOLLS N., PEDUZZI P., MECHLER R., BOUWER L., ARNELL N., MACH K., MUIR-WOOD R., BRAKENRIDGE G., KRON W., BENITO G., HONDA Y., TAKAHASHI K. & SHERSTYUKOV B. (2014) - *Flood risk and climate change: global and regional perspectives*. Hydrological Sciences Journal, **59** (1): 1-28.

LOPEZ-AVILES A. (2007) - *Flash flooding in Spain: geomorphological approaches supporting flood frequency analysis, and the implications for the design of structures*. Water and Environment Journal, **21** (3): 217-226.

MARAGOUDAKI R. & TSAKIRIS G. (2005) - *Flood mitigation planning using Promethee*. European Water, **9** (19): 51-58.

MORRISON J. & SMITH J. (2002) - *Stochastic modeling of flood peaks using the generalized extreme value distribution*. Water Resources Research, **38**(12): 1-12.

SHABANLOUS. (2014) - *Calculation of Flood Hydrograph for Karun Basin by DifferentMethods*. Agricultural Communications, **2** (2): 54-61.

SMITHERS J. (2012) - *Methods for design flood estimation in South Africa*. Water SA, **38**(4): 633-646.

STONEVIČIUS E. & VALIUŠKEVIČIUS G. (2018) - *Identification of Significant Flood Areas in Lithuania*. Water Resources, **45** (1): 27-33.

TARAWNEH E., BRIDGE J. & MACDONALD N. (2016) - *A pre-calibration approach to select optimum inputs for hydrological models in data-scarce regions*. Hydrology and Earth System sciences, **20**: 4391 – 4407.

TODOROVIC P. & ZELENHASIC E. (1970) - *A stochastic model for flood analysis*. Water Resources Research, **6** (6): 1641-1648.

TSAKIRIS G., KORDALIS N. & TSAKIRIS V. (2015) - *Flood double frequency analysis: 2D-Archimedean copulas vs bivariate probability distributions*. Environmental Processes, **2** (4): 705-716.

VILLARINI G., SMITH J., SERINALDI F., NTELEKOS A. & SCHWARZ U. (2012) - *Analyses of extreme flooding in Austria over the period 1951–2006*. International Journal of Climatology, **32**: 1178-1192.

VIVEKANANDAN N. (2014) - *Comparison of probability distributions for estimation of peak flood discharge*. Open Access Library Journal, **1**(e498). http://dx.doi.org/10.4236/oalib.1100498.

Received October 2019 – Accepted March 2020