

Study on the Frequency of Heavy Rainfall in Huong Khe District, Ha Tinh Province

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Abstract: Rainfall intensity, duration and frequency of 24 consecutive hours or longer (48h, 72h, 96h) are very essential for the assessment of flood risk and the design of the reservoirs and dams in Huong Khe district, Ha Tinh province. The analysis of flood-causing rainfall and the actual floods from 1990 to 2012 has shown that floods usually occur when: a) 24-hour continuous rainfall reacheds 710.6mm or more; b) Heavy rains which lasted longer than 24 hours and reached 548.9mm/24h to 630.2mm/48h or more; c) Heavy rains lasted from 72 hours to 96 hours and reached from 534.5mm/72h to 575.6mm/96h. The following conclusions have been drawn from analysis results of development of the empirical and theoretical exceedance frequencies of Pearson III distribution of 24h-96h heavy rainfall: a) All the theoretical and empirical frequency data have very high correlation coefficient from 0.891 (24h rainfall) to about 0.948 (72h-96h rainfall); b) For 24h rainfall, the actual rainfall of the empirical P of 13% to 26% is about 40mm lower than the theoretical rainfall, while the actual rainfall of the empirical P of 8.7% is about 80mm higher than the theoretical value, and that of the empirical P of 4.35% is about 175mm higher than the theoretical value; the actual rainfall at empirical P of 8.7% is corresponding to theoretical P of 4.5%, and actual rainfall at empirical P of 4.35% is corresponding to theoretical P of ~1%; c) For 48h and 72h rainfall, the empirical and theoretical frequency data are very close to each other for the P in the range of 8.7% to 30%, only empirical P of 4.35% is much far from theoretical one and corresponding to rainfall frequency of ~1%; d) For 96h rainfall, the empirical and theoretical frequency data are very close to each other for most P range, only empirical P of 8.7% and 4.35% are somehow far from theoretical ones and corresponding to rainfall of theoretical frequencies of ~4.5% and ~1%, respectively.

Keywords: Extreme, Frequency, Pearson, Gamma, Kritsky-Menken, Standard deviation, Coefficient of skewness.

1. Introduction

The natural disasters caused by extreme weather events, including floods due to heavy

rain frequently occur in Central Vietnam, particularly in the North Central region. Two or three of weather patterns causing heavy rain such as tropical cyclones, inter tropical convergence zone (ITCZ), meridional convergence, cold surges, etc., which are active simultaneously or consecutively, combined with regional topography, bring about the

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typical flooding Central region (Nguyen Khanh Van, 2009 and 2012) [1, 2]. Huong Khe district is located in the Southwest of Ha Tinh province and surrounded with two major mountains: Tra Son Mountain in the East is a branch of Eastern Annamite Range extending to the ocean, the natural boundary with three districts Can Loc - Thach Ha - Cam Xuyen; Giang Man Mountain in the West is a segment of the majestic Annamite Range, the border with Laos. Huong Khe district borders Vu Quang, Duc Tho districts in the North and Quang Binh province in the South. The topography of this district has two main types: the mountainous topography with the average elevation of 1,500 meters is complicatedly differentiated and strongly fragmented, forming different ecological zones; and the midland, hilly topography is the transition between high mountain and plain, along the Ho Chi Minh highway. With extreme weather patterns and fragmented hilly topography with severe slope, Huong Khe district often suffers from the heavy floods. Especially due to the impact of climate change, a lot of tropical cyclones, and devastating floods have continuously occurred in the Central region (Le Van Nghinh and Hoang Thanh Tung, 2006) [3].

One of the key parameters in assessment of flood magnitude, in design of reservoirs, in risk assessment of reservoir failure causing floods in the downstream area etc. is the rainfall frequency and magnitude in a certain period of time corresponding to that frequency. Vietnam Institute of Meteorology, Hydrology and Environment in 1999 [4] established a map of highest one-day rainfall for the Central region and Central Highlands with the frequency of 1% with data until 1999. However, with the availability of more new observed data, especially in the context of the climate change, the results may not be valid for the present time. Moreover, different values of frequency are required for different purposes of utilization. Also, different rainfall durations are required for different sizes of the area under flood assessment.

Le Van Nghinh (2004) [5] carried out the warning and prediction of beyond-design floods for medium and small reservoirs caused by heavy rainfalls. The study on selection of design flood criteria for designing emergency spillway carried out by Pham Ngoc Quy (2006) [6] indicated the importance of selection of beyond-design rainfall frequency. Such studies definitely require different values of frequency and corresponding rainfall magnitudes, which are possible expressed through frequency curves.

Nguyen Anh Tuan (2014) [7] determined the values of calculated daily rainfall according to the design frequency in 12 selected meteorological stations based on the data series of long actual rainfall from 1960 to 2010, in which the last time period was supposed to correspond to the new context of the impact of climate change, applied to calculate the design flow of small drainage works on the road in accordance with current design standard TCVN9845:2013 and determined the values of characteristic coefficient of the rain shape for the selected area in order to calculate the rainfall intensity corresponding to time of concentration of the basin and the design frequency used in the standard TCVN9845:2013. Ngo Le An (2016) [8] studied the details of change in the highest one-day rainfall (used to calculate design flood for medium and small basins) at some basins in the Central region and Central Highlands under the impact of climate change, according to the statistical method for error correction. Doan Thi Noi (2016) [9] carried out the study on temporal characteristics of flood, the analysis of development of rainfall frequency and intensity-duration-frequency curves for the Northern Vietnam in transportation design. The works' results are most relevant to the transport design, and is directly related to the one-day maximal rainfall only.

Meanwhile, in many cases of study and design, rainfall intensity, duration and frequency (IDF), 24h or more (48h, 72h, 96h, etc.) continuous rainfall are really essential for

the assessment of flood risk and the design of constructions, including reservoirs and dams. The paper aims to identify and develop the heavy rainfall frequencies in Huong Khe district, Ha Tinh province, which is located just in the South most of the Northern Vietnam central plain close to the Ngang mountainous pass, which is the natural topo-geographical boundary between Northern and Southern regions with distinguished heavy rainfalls (Nguyen Khanh Van, 2012) [2].

Huong Khe district is located in Ngan Sau River sub-basin, in Lam River basin (Dang

Dinh Kha et al., 2015) [10] and there is the meteorological observation station Huong Khe, level 2 (Figure 1) (but the rainfall measurement was hourly). In the East and Southeast of this station, there are two meteorological stations Ha Tinh and Ky Anh, observing the coastal area and coastal plains; in the Northwest, there is the meteorological station Huong Son, observing the meteorological characteristics of Ngan Pho River sub-basin. Therefore, in the article, the analysis of rainfall data in the meteorological station Huong Khe characterizes the Ngan Sau River sub-basin.

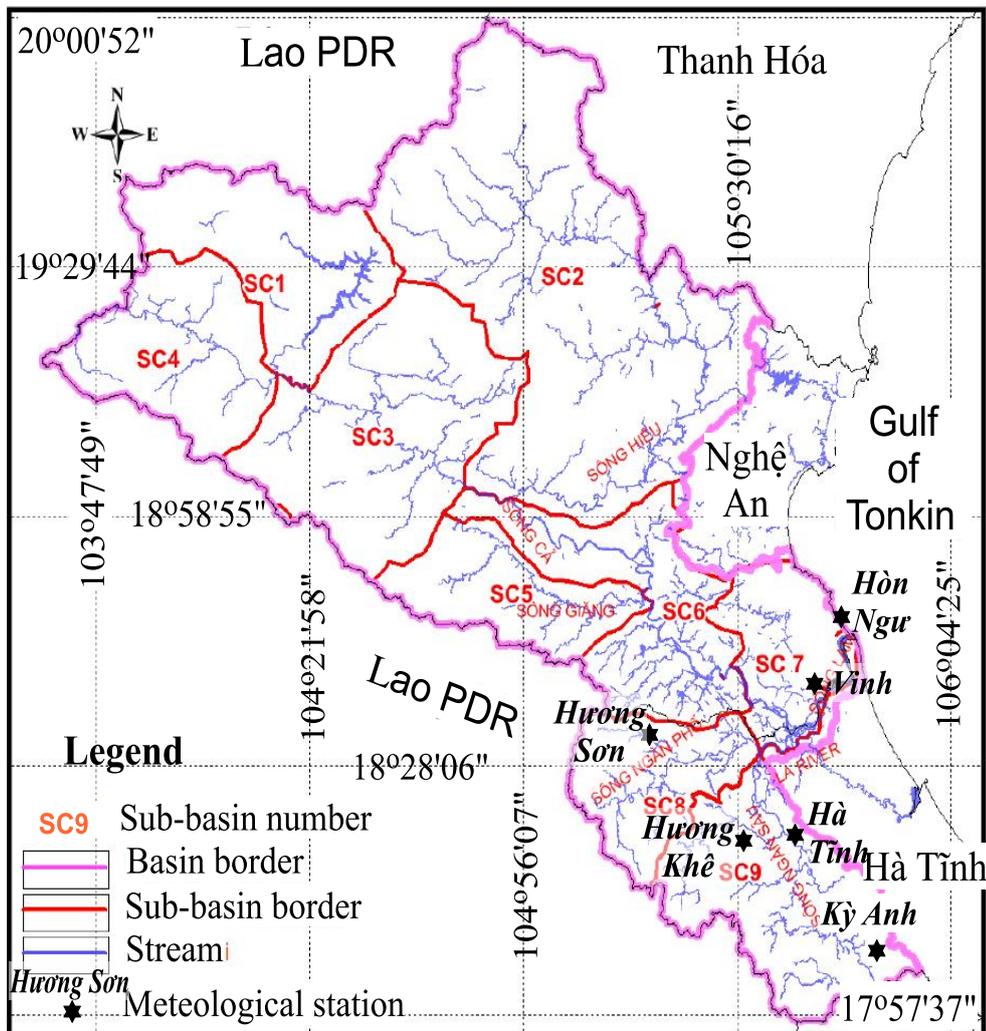


Figure 1. Boundaries between the sub-basins of Lam River basin [3].

2. The weather patterns causing flood and the characteristics of flood in the region

The weather patterns causing floods in Huong Khe – Ha Tinh are integral to those in the North Central region, including the following (Nguyen Khanh Van and Bui Minh Tang, 2004) [11]: tropical cyclones, inter tropical convergence zone (ITCZ), meridional convergence and cold surges. According to Nguyen Khanh Van and Bui Minh Tang (2004), in the past the flood-causing rainfalls in the

region had been occurred when there was a combination of three weather patterns – cool atmosphere, tropical convergence, with the following characteristics: 1) heavy rainfall duration is from 2 days to 8 days; 2) average duration of a single weather pattern is 2-3 days and the longest of 4 days; 3) average duration of the combination of weather patterns of 4-5 days. Accordingly, it is necessary to evaluate and determine the 48h or longer rainfall.

Table 1. Floods in Nghe An – Ha Tinh, duration of rainfall and exceedance frequency P in Huong Khe

No.	Year	From	To	Flood occurrence after number of days from heavy rain start	24h rainfall	48h rainfall	72h rainfall	96h rainfall
					(mm)	(mm)	(mm)	(mm)
					P (%)	P (%)	P (%)	P (%)
	1995			Flooding not occurred	269.3	500.9	538.6	552.6
1	1996	12/9	15/9	4	376.6	585.6	598.4	698.7
2	2002	19/9	22/9	4	13.0	13.0	13.0	13.0
					304.7	464.7	534.5	575.6
3	2007	6/8	8/8	1	21.7	21.7	21.7	17.4
					710.6	946.2	1129.4	1144.4
4	2010	01/10	5/10	4	4.3	4.3	4.3	4.3
					313.4	454.5	461.8	604.8
5	2010	15/10	17/10	2	~19	~15	~24	~15
					548.9	630.2	727.5	912.2
	2012			Flooding not occurred	8.7	8.7	8.7	8.7
					332.9	372.4	395.6	398.7

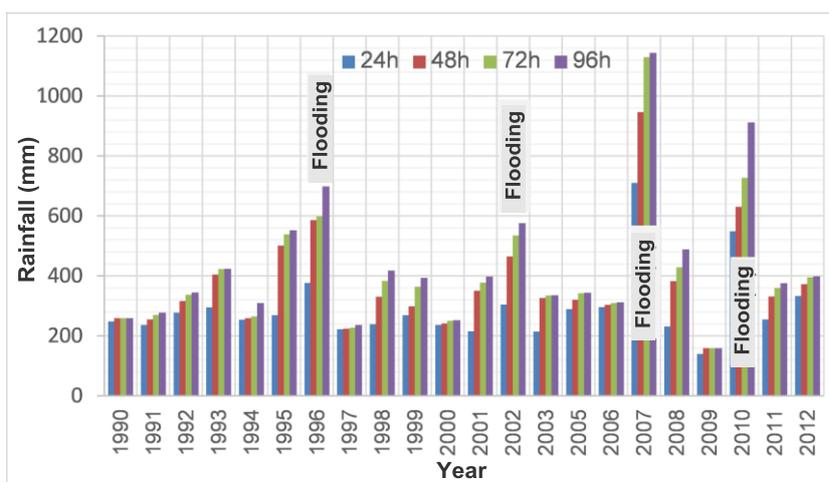


Figure 2. The highest continuous 24h-96h rainfall in Huong Khe district (1990-2012).

Additionally, this paper's authors have carried out statistical analysis on the temporal rainfall characteristics of great floods in the North Central region from 1990 to 2012 and presented the characteristics of duration and flood-causing rainfall in the research area (Table 1 and Figure 2).

It is well-known that in each heavy rain, rainfall intensity changes temporally and spatially. Meanwhile flood occurrence is a combination of many natural factors of topography, geology, vegetation, etc. and characteristics of the heavy rain (Geoffrey S. Dendy, 1987) [12]. Therefore, the conclusions about the causes of flood only based on the rainfall distribution of heavy rain are not complete. However, in the framework of research with the basis that flood has the close relationship with rainfall distribution of the heavy rain, and natural conditions remain unchanged or play the minor role, according to the research results of rainfall distribution, it is possible to draw some following remarks about the relationship between duration and flood-causing rainfall in Huong Khe district, Ha Tinh:

Flood occurs when the continuous 24h rainfall reaches 710.6mm (2007) (in 2010 despite the continuous 24h rainfall of 548.9mm, flood did not occur);

Flood occurs when the heavy rain lasts over 24h with the rainfall of over 548.9mm/24h and 630.2mm/48h (2010) (in 1995 the continuous 48h rainfall was 500.9mm/48h but flood did not occur);

Flood occurs when the heavy rain lasts from 72h to 96h with the rainfall of over 534.5mm/72h and 575.6mm/96h (2002) (in 1995 the rainfall of 538.6mm/72h to 552.6mm/96h did not cause the flood).

Thus, it is possible to affirm that the development of frequency curve of continuous 24h or longer rainfall has the practical significance in the assessment of flood risk in the region.

3. The data and method in development of rainfall frequency curve in Huong Khe district, Ha Tinh province

Data

Data used to build the maximum rainfall frequency of different durations are the hourly rainfall data measured at the meteorological station Huong Khe, in Huong Khe district, Ha Tinh province from 1990 to 2012 that are managed by National Meteorological Service, Ministry of Natural Resources and Environment [13]. This meteorological station belongs to the level 2 (the moderate detailed monitoring level), but the rainfall measurement belongs to level 1 (the most detailed monitoring level) since the measurement is every hour. The hourly rainfall data are used to calculate the maximal rainfall of continuous 24h, 48h, 72h, 96h to build the rainfall frequency curve.

Empirical cumulative frequency

Cumulative frequency (P), also known as empirical exceedance frequency is the ratio between the number of occurrences of random variable values (rainfall) that are greater than or equal to the value of x_m in a series of n effective data; the frequency P is determined by the following formula (Ven Te Chow et al., 1988) [14]:

$$P(X \geq x_m) = \frac{m-b}{n+1-2b} 100\% \quad (1)$$

where b is the parameter. When $b=0.5$, it corresponds to Hazen formula, $b=0.3$ – Tregodayev formula, $b=0$ – Weibull formula, $b=3/8$ – Blom formula, $b=1/3$ – Turkey formula and $b=0.44$ – Gringorten formula.

In reality, when conducting the calculation for the annual maximum value in determining the number of iterative years (T), U.S. Water Resources Council in 1981 used the value $b=0$, so $T=(n+1)/m$ and $P=m/(n+1)$. In this article, the authors use this formula in calculating the empirical frequency P .

The extreme value distribution for maximum rainfall

Extreme value distribution for maximum rainfall, which belongs to any class of distribution according to Fisher and Tippet (1928) (Ven Te Chow et al., 1988), always converges to one of three types of extreme values (EV) I, II and III (EVI, EVII, EVIII) when the data series is long enough. The properties of extreme value type I, type II and type III were developed by Gumbel in 1941, by Frechet in 1927 and by Weibull in 1939, respectively (Ven Te Chow et al., 1988) [14]. In 1955 Jenkings (Ven Te Chow et al., 1988) [14] demonstrated that these three types of extreme value distribution are the specific cases of a general distribution with probability distribution function as follows:

$$F(x) = \exp \left[\left(1 - k \frac{x-u}{\alpha} \right)^{1/k} \right] \tag{2}$$

where x is the extreme value; k , u and α are the parameters.

When $k=0$ corresponding to type I (also known as Gumbel distribution); $k<0$ corresponding to type II (also known as Frechet distribution), then the lower limit of x is $(u + \alpha/k) \leq x < \infty$; and when $k>0$ corresponding to type III, then the upper limit of x is $-\infty \leq x \leq (u + \alpha/k)$ (and in this case, the variable $-x$ is called the Weibull distribution).

In the study on rainfall distribution, the commonly used distributions are Pearson III and Kritsky-Menkel for type III and Gumbel for type I [15]. In this article, Pearson III and Krisky-Menkel distributions are used to determine the theoretical rainfall frequency in Huong Khe – Ha Tinh.

Pearson III distribution

Pearson III probability density function (also known as 3-parameter Gamma probability distribution) [14] of the random variable with value of x has the following form:

$$f(x) = \frac{\lambda^\beta (x - \varepsilon)^{\beta-1} e^{-\lambda(x-\varepsilon)}}{\Gamma(\beta)} \tag{3}$$

where Gamma distribution $\Gamma(\beta)$ is defined as:

$$\Gamma(\beta) = \int_0^\infty u^{\beta-1} e^{-u} du \tag{4}$$

with $x \geq \varepsilon$ (the lower limit of random variable); and three parameters of Gamma probability distribution are defined as follows:

$$\lambda = \frac{s_x}{\sqrt{\beta}}; \quad \beta = \left(\frac{2}{C_s} \right)^2; \quad \varepsilon = \bar{x} - s_x \sqrt{\beta} \tag{5}$$

where ε is the lower limit of random variable (position parameter); λ is the rate parameter; β is the shape parameter; \bar{x} is the average value; s_x is the standard deviation; C_s is the coefficient of skewness.

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i; \quad s_x = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n-1}}; \tag{6}$$

$$C_v = \frac{s_x}{\bar{x}}; \quad C_s = \frac{n}{(n-1)(n-2)} \sum_{i=1}^n \left(\frac{x_i - \bar{x}}{s_x} \right)^3$$

where n is the number of samples, C_v is the coefficient of variation.

When the variable that is greater than or equal to the value x has the occurrence exceedance probability P , then x is determined by the formula:

$$x = \varepsilon + INV(\Gamma(1 - P, \beta, \lambda)) \tag{7}$$

and conversely, the occurrence exceedance probability P of the variable that is greater than or equal to x is determined by the formula:

$$P(X \geq x) = \int_x^\infty f(x) dx \tag{8}$$

Kritsky-Menkel method

The limitation of Pearson III distribution is when $C_s < 2C_v$, the random variable has negative value that does not fit the physical significance of meteorological phenomenon. Accordingly, Kritsky and Menkel established the revised probability distribution named Kritsky-Menkel method (Kritsky S. N. and Menkel M. F., 1967) [15], using Pearson III probability density function when $C_s = 2C_v$ as the basis. To calculate the values of x , Kritsky-Menkel built the lookup table of the value Kp depending on $C_s = mC_v$, P and C_v . The value of random variable corresponding to the exceedance frequency P is calculated according to the formula $x = \bar{x} + Kp$.

4. The frequency curve of maximum continuous 24h, 48h, 72h, 96h rainfall in Huong Khe district, Ha Tinh province

At the hydrometeorological station Huong Khe, in Huong Khe district, Ha Tinh province, the rainfall is observed hourly. The data on hourly rainfall observed at the meteorological station Huong Khe have been collected. The continuous 24h, 48h, 72h, 96h rainfall is calculated by using the moving total method of hourly skewness and then the maximum

continuous 24h, 48h, 72h, 96h rainfall in the year is also determined. The rainfall frequency is determined by above empirical formula (1) (Ven Te Chow et al., 1988) [14] with the parameter value $b=0$. The methodology to calculate the parameters of Pearson III empirical and theoretical frequencies has been applied to each case of the maximum continuous 24h, 48h, 72h, 96h rainfall. The parameters of the frequency according to Pearson III distribution that has been calculated are average value \bar{x} , standard deviation s_x , coefficient of skewness C_s , coefficient of variation C_v , position parameter ε , shape parameter β , and rate parameter λ . The results of empirical frequency are shown in Table 2 that is the database to develop the Pearson III theoretical frequency.

By using Pearson III method and applying the statistical probability according to the formulas from (5) to (8), the Pearson III theoretical frequency and the parameters of distribution as well as statistical probability presented in Table 3 have been determined. The empirical and theoretical exceedance frequencies P of Pearson III distribution of continuous 24h-96h rainfall are shown in Figures 3-6.

Table 2. The maximum continuous 24h-96h rainfall and the exceedance probability

Year	24h		48h		72h		96h	
	rainfall (mm)	P (%)						
1990	247.8	60.87	259.1	73.91	259.1	82.61	259.1	82.61
1991	236.6	69.57	254.7	82.61	270.2	73.91	277.1	78.26
1992	277.5	39.13	316.3	60.87	337.0	60.87	345.0	56.52
1993	295.2	30.43	404.2	26.09	423.3	30.43	423.9	30.43
1994	254.4	56.52	258.9	78.26	264.5	78.26	309.5	73.91
1995	269.3	47.83	500.9	17.39	538.6	17.39	552.6	21.74
1996	376.6	13.04	585.6	13.04	598.4	13.04	698.7	13.04
1997	221.7	82.61	223.7	91.30	226.7	91.30	236.0	91.30
1998	238.5	65.22	330.3	47.83	383.5	39.13	418.2	34.78

1999	269.5	43.48	298.5	69.57	364.1	47.83	393.6	47.83
2000	236.4	73.91	241.4	86.96	250.5	86.96	252.3	86.96
2001	215.1	86.96	350.5	39.13	377.5	43.48	397.9	43.48
2002	304.7	21.74	464.7	21.74	534.5	21.74	575.6	17.39
2003	214.3	91.30	326.3	52.17	334.3	65.22	335.1	65.22
2005	289.0	34.78	320.2	56.52	342.4	56.52	343.5	60.87
2006	296.2	26.09	303.5	65.22	309.4	69.57	311.9	69.57
2007	710.6	4.35	946.2	4.35	1129.4	4.35	1144.4	4.35
2008	231.5	78.26	382.4	30.43	429.0	26.09	488.7	26.09
2009	139.7	95.65	159.1	95.65	159.3	95.65	159.4	95.65
2010	548.9	8.70	630.2	8.70	727.5	8.70	912.2	8.70
2011	255.2	52.17	330.9	43.48	359.8	52.17	375.9	52.17
2012	332.9	17.39	372.4	34.78	395.6	34.78	398.7	39.13

Table 3. The parameters of statistical probability and Pearson III distribution

Rainfall duration	Average value \bar{x}	Standard deviation s_x	Coefficient of skewness C_s	Coefficient of variation C_v	Parameters			Correlation coefficient R^2
					Position ϵ	Shape β	Rate λ	
24h	293.71	121.29	2.46	0.41	194.95	0.66	148.95	0.891
48h	375.45	170.94	2.01	0.46	170.94	0.99	172.07	0.943
72h	409.75	207.49	2.22	0.51	222.56	0.81	230.00	0.932
96h	436.79	229.64	1.87	0.53	190.08	1.15	214.37	0.948

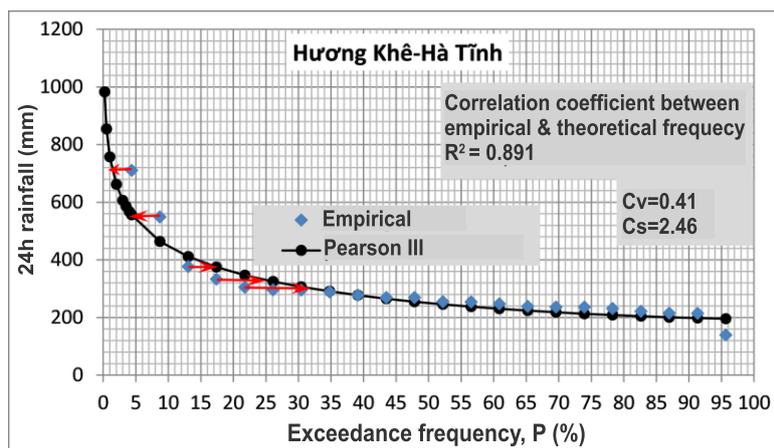


Figure 3. Empirical frequency and Pearson III distribution of continuous 24h rainfall (1990-2012).

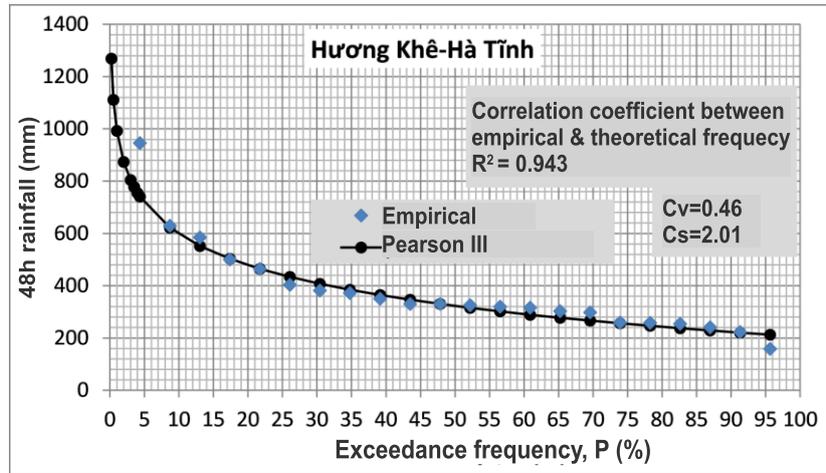


Figure 4. Empirical frequency and Pearson III distribution of continuous 48h rainfall (1990-2012).

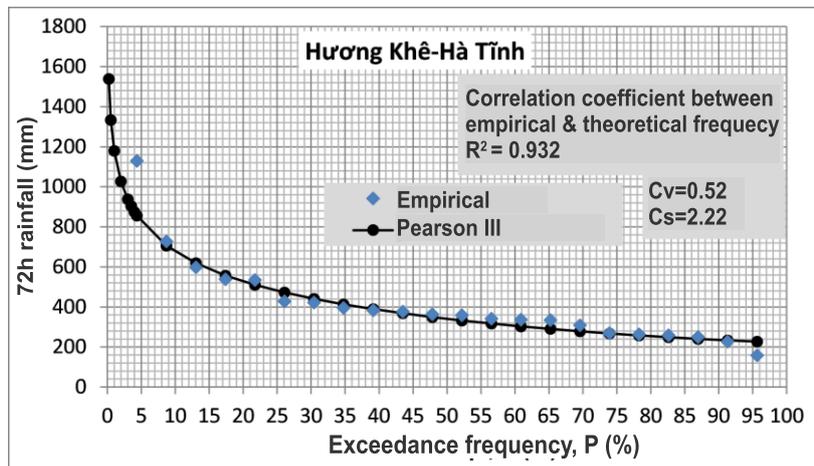


Figure 5. Empirical frequency and Pearson III distribution of continuous 72h rainfall (1990-2012).

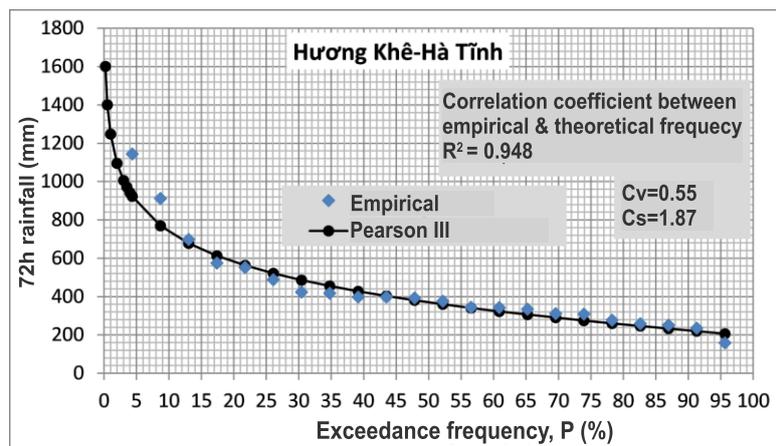


Figure 6. Empirical frequency and Pearson III distribution of continuous 96h rainfall (1990-2012).

5. Conclusions and discussions

Based on rainfall duration and intensity in the period of 1990-2012, the flood-causing rainfall in Huong Khe, Ha Tinh has the following characteristics:

- Flood occurs when the continuous 24h rainfall reaches 710.6mm (2007) or more;

- Flood occurs when the heavy rain lasts from 24h to 48h with the rainfall of over 548.9mm/24h and 630.2mm/48h (2010);

- Flood occurs when the heavy rain lasts from 72h to 96h with the rainfall of over 534.5mm/72h and 575.6mm/96h (2002).

This is the basis for the prediction of flood risk in the region according to the rainfall trend analysis of heavy rain of under 24h that can cause flood, or heavy rain of over 24h that does not cause flood, but can lead to flood in the area when it continues to last over 24h.

Based on the determination of empirical and theoretical exceedance frequencies of Pearson III distribution of continuous 24h-96h rainfall, it is possible to draw some following remarks and discussions:

All the theoretical and empirical frequency data have very high correlation coefficient from 0.891 (24h rainfall) to about 0.948 (72h-96h rainfall);

- For 24h rainfall, the actual rainfall of the empirical P of 13% to 26% is about 40mm lower than the theoretical rainfall, while the actual rainfall of the empirical P of 8.7% is about 80mm higher than the theoretical value, and that of the empirical P of 4.35% is about 175mm higher than the theoretical value; the actual rainfall at empirical P of 8.7% is corresponding to theoretical P of 4.5%, and actual rainfall at empirical P of 4.35% is corresponding to theoretical P of ~1% (presented by red arrows in Figure 2). This is consistent with the actual flooding in the region when the flood in 2007 is considered the historic hundred-year flood.

- For 48h and 72h rainfall, the empirical and theoretical frequency data are very close to each

other for the P in the range of 8.7% to 30%, only empirical P of 4.35% is much far from theoretical one and corresponding to rainfall frequency of ~1%;

- For 96h rainfall, the empirical and theoretical frequency data are very close to each other for most P range, only empirical P of 8.7% and 4.35% are somehow far from theoretical ones and corresponding to rainfall of theoretical frequencies of ~4.5% and ~1%, respectively.

Furthermore, in accordance with Nguyen Khanh Van et. al. (2013) [16], there is a certain relationship between the resonant influences of topo-geographic conditions in spatial heavy rainfall patterns in the Coastal Central Region of Vietnam, it would be a scientific and practical significance of a study on the different exceedance frequency distributions of extreme rainfalls over the areas along N-S direction by E-W orientation mountain ranges (the Ngang, the Hai Van and the Ca mountainous passes).

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Nghiên cứu tần suất mưa lớn khu vực huyện Hương Khê tỉnh Hà Tĩnh

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Tóm tắt: Cường độ mưa theo thời đoạn mưa, tần suất mưa và lượng mưa liên tục 24h hoặc dài hơn (48h, 72h, 96h) là rất cần thiết cho các công tác đánh giá nguy cơ lũ lụt và thiết kế các công trình hồ đập khu vực huyện Hương Khê tỉnh Hà Tĩnh. Các kết quả phân tích đặc trưng mưa gây lũ và thực tế lũ lụt tại khu vực từ năm 1990 đến 2012 cho thấy khu vực xảy ra lũ lụt khi: a) Mưa liên tục 24h đạt tới 710,6mm; b) Mưa lớn kéo dài liên tục trên 24h với lượng mưa đạt tới trên 548,9mm/24h và tới 630,2mm/48h; c) Thường xảy ra lũ lụt khi mưa lớn kéo dài trên 72h đến 96h, với lượng mưa đạt tới trên 534,5mm/72h và tới 575,6mm/96h. Kết quả phân tích xây dựng đường tần suất (P) vượt thực nghiệm và tần suất lý luận Pearson III mưa lớn liên tục 24h-96h cho kết quả: a) Tất cả các đường tần

suất vượt lý luận và thực nghiệm có hệ số tương quan rất chặt chẽ, thấp nhất là 0,891 (mưa liên tục 24h) và tới khoảng 0,948 (mưa liên tục 72h-96h); b) Đối với mưa liên tục 24h, lượng mưa thực tế ở các P thực nghiệm từ 13% đến 26% thấp hơn lượng mưa lý luận khoảng 40mm, trong khi đó lượng mưa thực tế ở các P thực nghiệm 8,7% cao hơn lượng mưa lý luận khoảng 80mm, và ở P thực nghiệm 4,35% cao hơn khoảng 175mm; lượng mưa ở P thực nghiệm 8,7% tương đương với P lý luận ~4,5% và lượng mưa ở P thực nghiệm 4,35% tương đương với P lý luận ~1%; c) Đối với mưa liên tục 48h và 72h, các đường tần suất lý luận và thực tiễn rất gần nhau ở dải giá trị 8,7% đến 30%, chỉ riêng P thực nghiệm 4,35% nằm lệch tương đối lớn và tương ứng với lượng mưa tần suất lý luận ~1%; d) Đối với mưa 96h, các đường tần suất lý luận và thực tiễn cũng rất gần nhau ở mọi dải giá trị, chỉ riêng P thực nghiệm 8,7% và 4,35% nằm lệch tương đối lớn, và tương ứng với lượng mưa tần suất lý luận ~4,5% và ~1%.

Từ khóa: Cực trị, tần suất, Pearson, Gamma, Kritsky-Menken, độ lệch chuẩn, hệ số thiên lệch.