Gumbel's Extreme Value Distribution for Flood Frequency Analyses of Timis River

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Abstract

One of the major problems in the engineering design of water resource is the estimation of peak flood flows. In probability theory and statistics, flood frequency analysis is used to obtain the distribution of flood probabilities. Gumbel distribution represents distributions of extreme values used in hydrological studies to predict flood peak, maximum rainfall, etc. This paper aims to analyses the frequency of floods, Gumbel's frequency distribution method, based on the maximum annual flows in the Timis River for the period of 30 years (1993 – 2022). For this analysis the return period (T) used is 5 years, 10 years, 50 years, 100 years, 150 years.

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1. Introduction

In this research, the flood frequency analysis approach was constructed depending upon the annual maximum peak discharge for 30 years. Flood frequency analysis is the estimation of how often a certain event will occur. Before the estimation is made, the analysis of the flow rate data plays a very important role in order to obtain a flood probability distribution [1].

Flood frequency analysis is most used by specialists in estimating peak flood amounts for a set of non-exceedance probabilities. Flood frequency analysis is used for the design of hydrotechnical works (dams, bridges, spillways, dykes, etc.) and for risk assessment in flood zones [2].

Firstly, the negative consequences of flooding on the environment would be decreased. By mapping the areas at risk of flooding, we can prevent future activities that affect the environment (like waste treatment plants, chemical industries, etc.) in flood prone areas or adapt those activities to the flood risks.

Materials and Methods

Study Area

Banat hydrographical space is located in the southwestern part of Romania and occupies an area of 18,320 km^2. Timiş River springs from the Semenic Mountains, with a length of 244 km on Romanian territory. Banat hydrographical area has a moderate temperate continental climate with sub-Mediterranean influences, and the multiannual average temperature is 6 °C. As for the precipitation, it's had values of 500 mm in the lowland areas, and 1,000 – 1,200 mm are recorded in the highlands. The total area of Timis River watershed is 7,310 km^2 and the main tributaries are the Bistra River and the Bârzava River. The geographical location of this area is between the parallels of 45°06'03'' and 45°45'50'' northern latitude, and in longitude it runs between 20°50'23'' and 22°45'50'' (Figure 1).

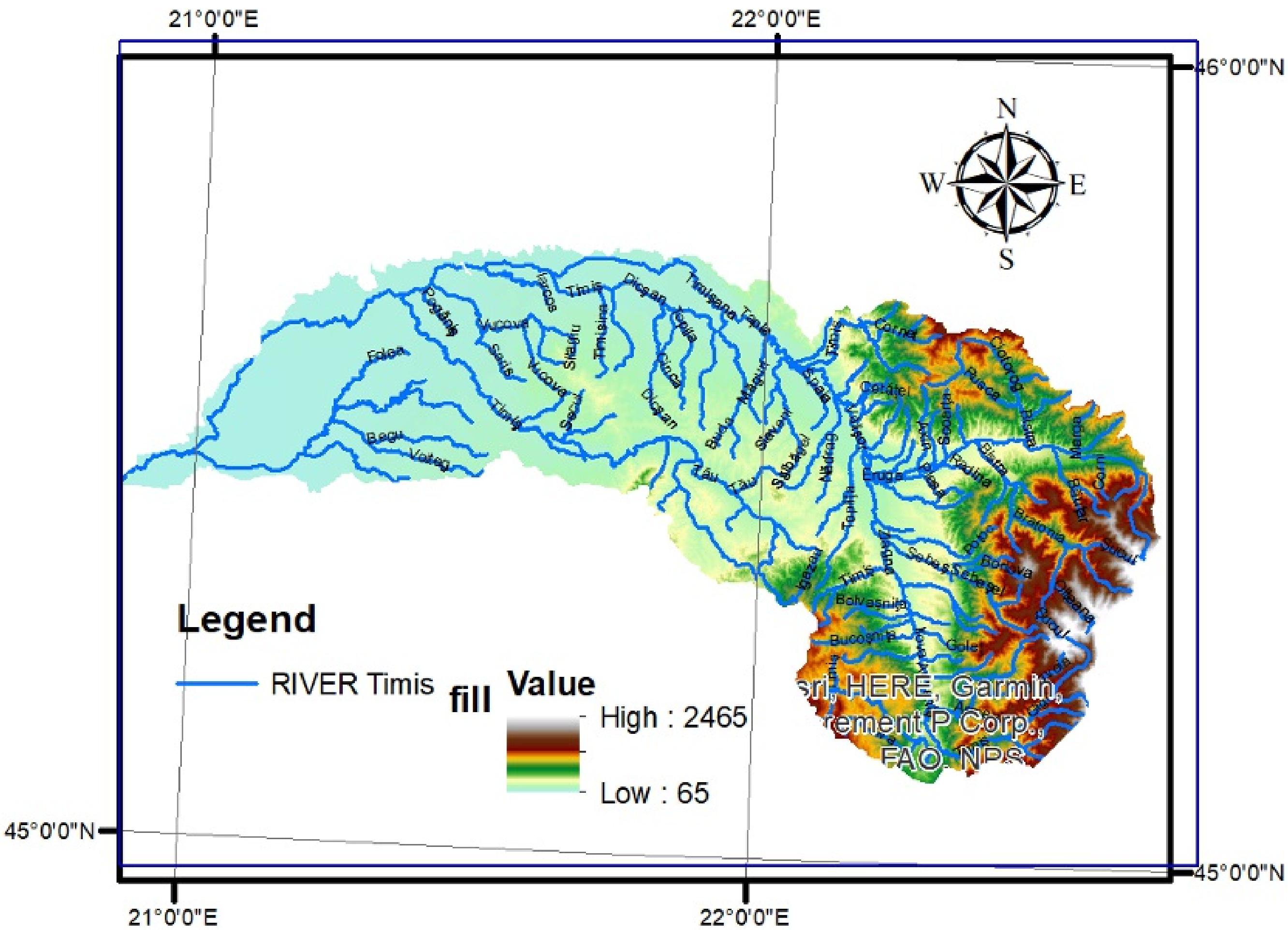

Figure 1. The study area map

Methods

The Gumbel distribution method, of frequency analysis requires a minimum of ten years of peak historical data to determine the future probabilistic prediction. In this study, the Gumbel frequency distribution method (Eq. 1) was applied to predict the flood frequency in the Timis river basin.

$$F_x(x) = \exp\left[-\exp\left(-\frac{x-u}{\alpha}\right)\right] = p$$

The mean value is calculated by summing all the individual values and dividing by the number of individual data values (Eq. 2).

$$\bar{x} = \sum_{i=1}^{n} \frac{x_i}{n}$$

$$\tau = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{(n-1)}}$$

The Gumbel's Distribution time dependent probability frequency analysis equation is (4)

$$X_T = \bar{x} + K \cdot \tau$$

Where: X_T is Gumbel's Distribution in reference to return period; $\bar{x}$ is the mean value; σ is the standard deviation; K is the factor of frequency

3. Discussion and Conclusion

To estimate the design flood for different return periods with the Gumbel method, from the series of maximum annual floods (table 1) for 30 years, the average value and the standard deviation (τ) is calculated. The average value ($\bar{\ }$) is calculated by the ratio between the summation of all values of the maximum annual flows and the total number of values of the series.

The most widely used measure of dispersion is the standard deviation, defined as the square root of the mean square of the deviations from the average value.

To calculate the estimates of exceedance probabilities associated with the peak flows in Table 1, Gringorten's position representation formula is used:

$$q_i = \frac{i-a}{N+1-2a}$$

Where:

- q_i - Exceedance probability associated with a specific observation.
- N - Number of annual maxima observations.
- I - Rank of specific observation
- a – 0.44, constant for estimation using Gringorten's method

Next, it was calculated the probability (p), the reduced variate (Y), respectively (T_p) - represents the estimated distribution of the 30 years of data.

$$Y = -\left[\ln \cdot \ln\left(\frac{T}{T-1}\right)\right]$$

Tabel 1. The annual maximum at Lugoj hydrometric station

Rank	Year	Q(m^3/s)	q_i	p_i	T_p	Y
1	2000	1247	0.0186	0.9814	53.786	3.9756
2	2020	1173	0.0518	0.9482	19.308	2.9340
3	2005	1135	0.0850	0.9150	11.766	2.4211
4	2006	592	0.1182	0.8818	8.461	2.0732
5	2001	571	0.1514	0.8486	6.605	1.8069
6	2019	566	0.1846	0.8154	5.417	1.5893
7	1998	544	0.2178	0.7822	4.591	1.4039
8	1999	543	0.2510	0.7490	3.984	1.2413
9	1995	519	0.2842	0.7158	3.519	1.0956
10	2014	498	0.3174	0.6826	3.151	0.9627
11	2010	470	0.3506	0.6494	2.852	0.8400
12	2016	450	0.3838	0.6162	2.606	0.7253
13	2007	406	0.4170	0.5830	2.398	0.6170
14	2015	377	0.4502	0.5498	2.221	0.5138
15	1997	372	0.4834	0.5166	2.069	0.4148
16	1996	343	0.5166	0.4834	1.936	0.3190
17	2013	329	0.5498	0.4502	1.819	0.2256
18	2008	297	0.5830	0.4170	1.715	0.1339
19	2009	287	0.6162	0.3838	1.623	0.0433
20	1993	276	0.6494	0.3506	1.540	-0.0470
21	2021	273	0.6826	0.3174	1.465	-0.1377
22	1994	264	0.7158	0.2842	1.397	-0.2296
23	2004	241	0.7490	0.2510	1.335	-0.3238
24	2018	229	0.7822	0.2178	1.278	-0.4215
25	2002	221	0.8154	0.1846	1.226	-0.5245
26	2022	219	0.8486	0.1514	1.178	-0.6354
27	2012	196	0.8818	0.1182	1.134	-0.7587
28	2003	183	0.9150	0.0850	1.093	-0.9023
29	2017	179	0.9482	0.0518	1.055	-1.0854
30	2011	113	0.9814	0.0186	1.019	-1.3825

N	=	30	year
Mean	=	437.1	m^3/s
std. dev	=	287.8061	m^3/s
Yn	=	0.5362	
Sn	=	1.1124	

– and are selected from Gumbel's extreme volume distribution table considered depending on sample size (n).

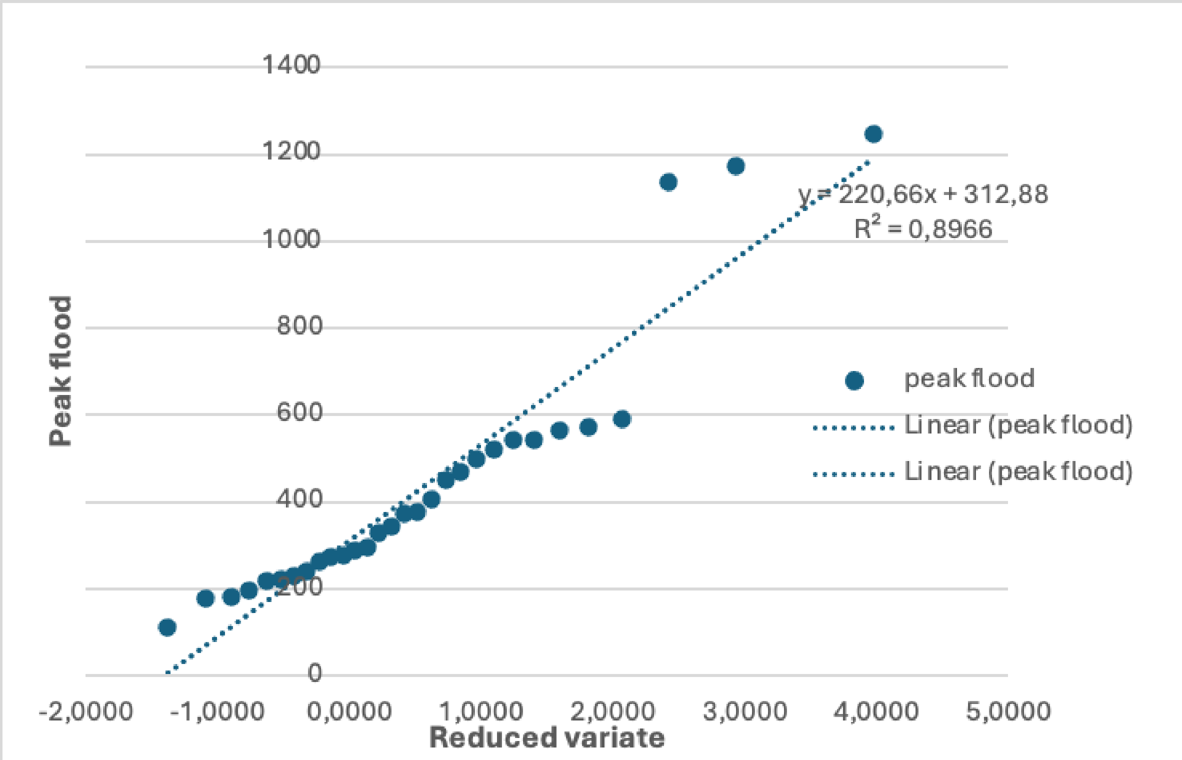

Figure 2. The plot of reduced variate vs. peak flood

From the equation of the trend line, it shows that R^2 has the value of 0.8966, and the maximum flow recorded at the hydrometric station Lugoj is 1247 mc/s since 2000, while the lowest flow is 113 mc/s which was recorded in 2011.

The average of 30 years is of 437.1 mc/s. The computation of annual peak discharge for return period of 5 years, 10 years, 50 years, 100 years, 150 years are presented in table 2.

Table 2. The parameters for flood frequency analysis

T	Y_T	K	$X_T(m^3/s)$
5	1.49994	0.866361	686.444
10	2.2503673	1.540963	880.5986
50	3.9019387	3.025655	1307.902
100	4.6001492	3.653316	1488.547
150	5.0072927	4.019321	1593.885

The table above shows the most important parameters for flood frequency analysis and the results of this study.

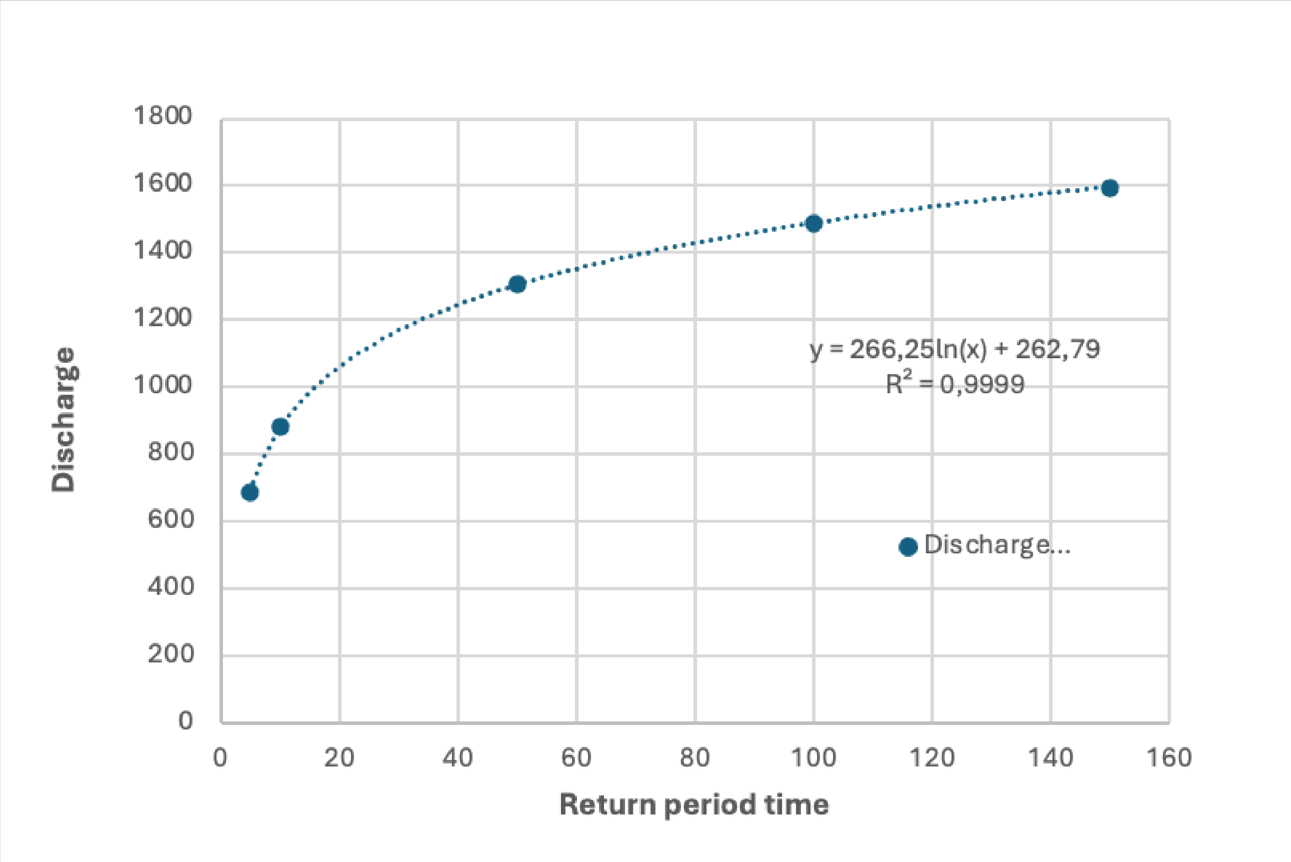

Figure 4. Flood Frequency Analysis Graph

The results illustrate the flows analysed for a return period of 5 years, 10 years, 50 years, 100 years, 150 years and 10,000 years are: 686.444 mc/s , 880.5986 mc/s, 1307.902 mc/s, 1488.547 mc /s and 1593.885872 m3/s. From the regression analysis equation, R^2 gives a value of 0.999 which shows that Gumbel's distribution is suitable for predicting the expected discharge in the river.

Other References

- ----------, 1969, Estimation of maximum floods", Technical Note, no. 98, WMO 233.
- Chow, V. T., Maidment, R., Mays, L. W. (1988), "Applied Hydrology". McGraw Hill Book Company, Singapore.
- Shaw, E.M., 1983, "Hydrology in Practice". Van Nostrand Reinhold, UK
- Gh. Cretu, C. Badaluta Minda, 2007, Model for floods simulation and floods occurred due to the breaching of the longitudinal defense hydro technical works, International conference "Disaster and pollution monitoring" , Iasi, Romania , pg. 47-54

References

1. ^*U. N. Ahmad, A. Shabri, and Z. A. Zakaria, "Flood frequency analysis of annual maximum stream flows using L-*

Moments and TL-Moments." Applied Mathematical Sciences, vol. 5, pp. 243– 253, 2011.

2. ^*Report, 1989, Statistical distributions for flood frequency analysis, world meteorological organization operational hydrology report No. 33, 1989*