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Flood Frequency Analysis of Akçay Stream

Mehmet Sandalcı*[1]

ABSTRACT

It is extremely important to predict floods for planning water systems and reducing flood damage. For the Akçay stream, which is one of the important branches of the Sakarya river , the floods that can be seen at certain time frequencies have been estimated. Normal (Gauss), log-normal and Gumbel distributions have been used in this context. The suitability of the distributions is investigated using Kolmogorov-Smirnov test and log-normal distribution is appropriated. As a result, the 100-year flood discharge is found to be 7,52 m3/s on log-normal distribution.

Keywords: Flood recurrence, probability distributions, Kolmogorov-Smirnov test, Akçay stream

1. INTRODUCTION

The management of drinking and usage water in parallel with the population is driving the various water resources. In response to this situation, the municipality of Sakarya, Sakarya Water Sewerage Administration (SASKI) planned a dam on Akçay in order to supply water for drinking and usage. The dam construction is almost complete and is expected to be opened soon.

It is vital importance to know the flood events which are extremely important in the design of river structures in this framework. As it is known, due to floods, the hydrological balance in the basin is disturbed and It can be large amount of life and property losses [1].

Estimation of flood discharges is crucial in reducing flood damage and designing water structures. Estimation of floods using statistical methods is widely used in hydrology. It is possible to reduce the loss of goods and lives by predicting flood events.

Hydrological data are tested with probability distributions since they have random variable characteristics. On the other hand, the most appropriate distribution to the data and the accuracy of the predictions made should be determined [2].

Normal, log-normal and Gumbel distributions are commonly used in determining the flood discharges. While the most appropriate distribution is determined, suitability tests such as method of Kolmogrov-Simirnov are used.

In this study, amount of flood discharges were estimated in different periods of 5, 10, 25, 50, 100, 250 years to increase the reliability of water structures on Akçay, provide flood control and reduce the damage of flood.

* Corresponding Author Mehmet Sandalcı
[1] Affiliation, e-mail sandalci@sakarya.edu.tr

2. FLOOD FREQUENCY ANALYSIS

The appropriateness of a given distribution in hydrologic frequency analyses is not known precisely [3]. But there are many methods developed for flood analysis. The most commonly used Kolmogrov-Simirnov (K-S) test, which is most commonly used for normal, log-normal and Gumbel distributions and the appropriateness of distribution, is briefly described below.

2.1. Normal Distribution (Gauss Distribution)

A normal distribution in a variety x with mean μ and variance σ^2 is a statistic distribution with probability density function, on the domain $x \in (-\infty, +\infty)$ [4].

$$p(x) = \frac{1}{\sigma\sqrt{2\pi}} exp[-(x-\mu)^2/2\sigma^2] \quad (1)$$

Eq. (2) is used to tabulate the probability density and probability distribution functions of the normal distribution [5].

$$z=(x-\mu)/\sigma \quad (2)$$

2.2. Log-normal Distribution

The log-normal is a probability distribution which has random variable logarithmic normal distribution. If y is a random variable with normal distribution, then the probability distribution for x = exp (y) is a log-normal distribution. In this case the log-normal probability density function is as follows [5].

$$(x) = P(y)\left|\frac{dy}{dx}\right| = \frac{1}{\sigma_y\sqrt{2\pi}} exp\left[\left(lnx - \mu_y\right)^2 / 2\sigma_y^2\right]\frac{1}{x} \quad (3)$$

Where, μ_y and σ_y are the mean and standard deviation of the y variable as follows.

$$\mu_x = exp\left(\mu_y + \frac{\sigma_y^2}{2}\right) \quad (4)$$

$$\sigma_x = \mu_x\left(e^{\sigma_y^2} - 1\right)^2 \quad (5)$$

2.3. Gumbel Distribution

If the probability of overturning a flood deficit is denoted by P, then according to the Gumbel distribution,

$$p(x) = 1 - exp[-exp(-y)] \quad (6)$$

by simplifying the equation (6)

$$y = ln[\ln(1-p)] \quad (7)$$

Where,

p is the probability of observing events. The parameters of the Gumbel distribution are α and β. α and β found as follows [5].

$$\alpha = \frac{1{,}2825}{\sigma_x} \quad (8)$$

$$\beta = \mu_x - 0{,}450\ \sigma_x \quad (9)$$

2.4. Kolmogorov-Smirnov (K-S) Test

The Kolmogorov-Smirnov (K-S) test, which is widely used in hydrology, is most commonly given by the equation (10).

$$\Delta = {}^{max}_{i}|F(x_i) - F_a(x_i)| \quad (10)$$

Where $F(x_i)$ is the ordinate corresponding to the selected x_i distribution function, and $F_a(x_i)$ is the additive frequency distribution ordinal calculated from the observed sample [6].

3. STUDY AREA AND DATA

Akçay Stream, which is one of the important branches feeding the Sakarya River, is located between 40^{0}33'44,47"N-30^{0}07'27,88"E and 40^{0}39'46,52"N-30^{0}22' 13,65"E coordinates. The source of Akcay is in Eskiyayla region from north-east of Geyve and joins to the Sakarya River from the neighbourhood of Adliye Village after joining with many small creeks. Gümüşdere, Karakütük Stream, Göçlük Stream, Mandura Stream, Hacıömer Stream and Kırca Stream can be shown as the tributaries that supply Akçay. Akçay stream has a total length of 25 km and has a basin area of approximately 20 km^2 [7]. A satellite image of Akçay is given in Figure 1.

Current measurements have been made on the river since 1957 in Dokurcun by AGI (Stream Gauging Station). The annual maximum flows during the 27-years period between 1983 and 2009 are specified as observed data and are given in Table 1. The annual mean maximum flow is 2,64m^3/s. The minimum and maximum values of long-term annual mean currents are 0,44 m^3/s and 6,72 m^3/s.

Figure 1.Satellite image of Akçay

Table 1. The Annual Maximum Flows

Years	1983	1984	1985
Flows(m^3/s)	5,45	2,67	2,65
Years	1986	1987	1988
Flows(m^3/s)	2,63	5,4	2,23
Years	1989	1990	1991
Flows(m^3/s)	0,71	2,04	2,15
Years	1992	1993	1994
Flows(m^3/s)	3,48	2,10	1,43
Years	1995	1996	1997
Flows(m^3/s)	2,75	2,89	**6,72**
Years	1998	1999	2000
Flows(m^3/s)	2,75	0,75	3,01
Years	2001	2002	2003
Flows(m^3/s)	**0,44**	2,81	2,99
Years	2004	2005	2006
Flows(m^3/s)	3,09	1,55	2,6
Years	2007	2008	2009
Flows(m^3/s)	1,86	2,75	1,49

4. RESULTS AND ANALYSIS

The flood discharges of 5, 10, 25, 50, 100 and 250 years belonging to different periods of Akçay in the study area are estimated by using normal, log-normal and Gumbel distributions. The values obtained Table 2. In addition, Kolmogorov-Smirnov (K-S) test and R^2 were performed to determine the most suitable distribution and the results of test are given in Table 3.

Table 2. Flood Recurrences for Different Distributions

Flood recurrence	Probability Distributions		
	Gauss Distribution (m^3/s)	Log-Normal Distribution (m^3/s)	Gumbel Distribution (m^3/s)
Q_5	3,80	3,53	3,63
Q_{10}	4,40	4,39	5,12
Q_{25}	5,05	5,52	6,43
Q_{50}	5,46	6,40	7,39
Q_{100}	5,92	**7,52**	8,36
Q_{250}	6,29	8,59	9,62

Table 3. Results of Kolmogorov-Smirnov (K-S) Test and R^2

Distribution	$\Delta_{max.}$	$\Delta\alpha$ Values	R^2
Gauss	0,20	0,29	0,9187
Log-Normal	**0,16**	0,29	**0,9350**
Gumbel	0,28	0,29	0,8838

The variation of the observed and estimated frequencies, trend line, R^2 are given in Figures 2, 3 and 4.

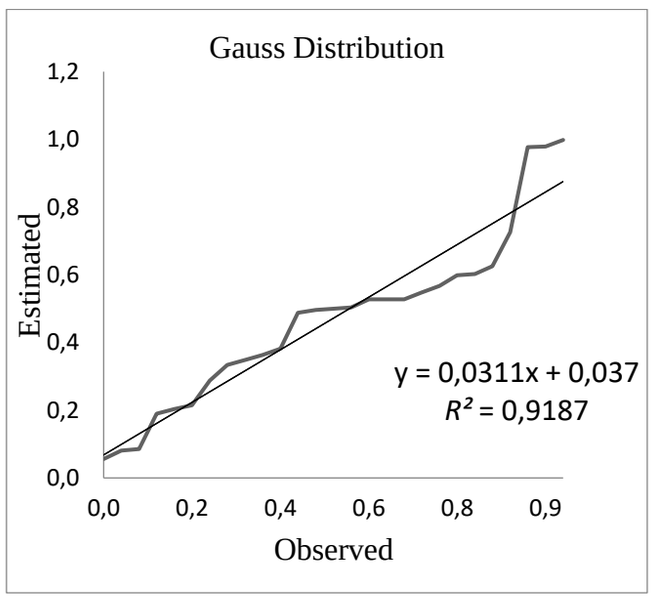

Figure 2. Frequencies According to the Normal Distribution

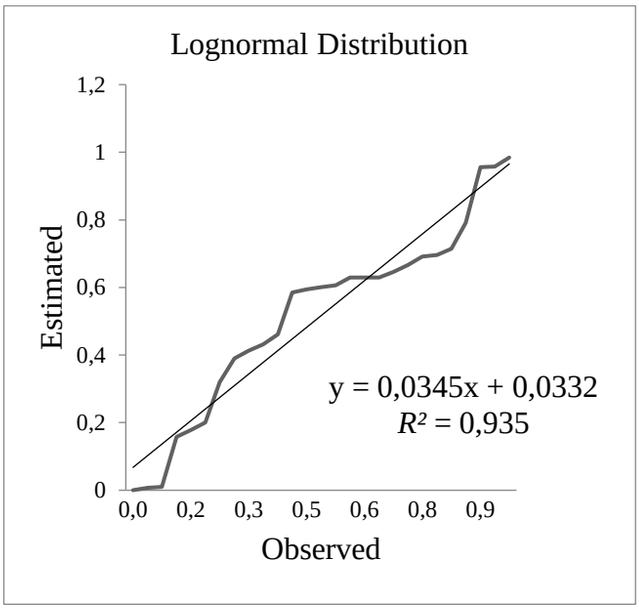

Figure3. Frequencies According to the Log-Normal Distribution

On the other hand, the function between distributions was investigated and the correlation coefficient was found. These values are given in Table 4.

Table 4. The Correlations Coefficient of the Distributions

Probability Distributions	Correlation Coefficient
Gauss-Gumbel	0,9977
Log-normal- Gumbel	0,9948
Gauss-Log-normal	0,9918

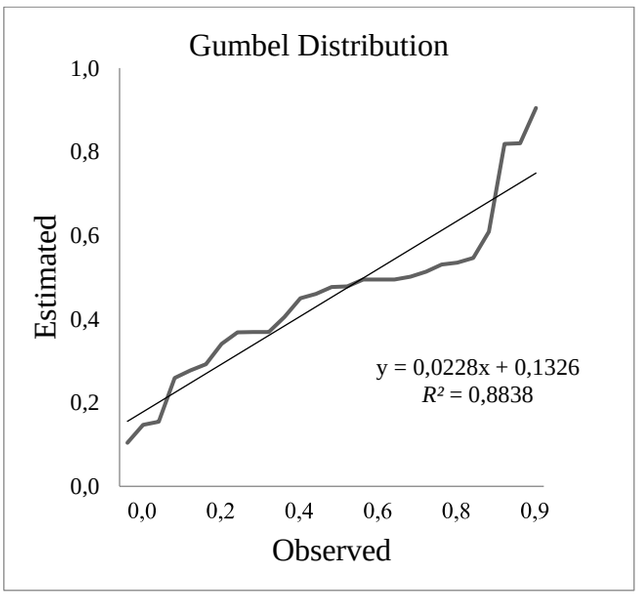

Figure 4. Frequencies According to the Gumbel Distribution

The results obtained in the study are listed below.

1-) From Table 1, the annual mean maximum flows value is 2,64 m^3/s. The minimum and maximum values of long-term annual mean currents are 0,44 m^3/s and 6,72 m^3/s.

2-) From Table 3, due to log-normal Δ_{max}=0,16 ≤Gauss Δ_{max}=0,20 ≤ Gumbel Δ_{max}=0,28 ≤ Δ_{α} =0,29 all distribution functions are suitable. However, the smallest Δ_{max} is log-normal Δ_{max} = 0,16. Therefore, the log-normal distribution is chosen as the most appropriate distribution.

3-) It is understood from Table 4 that the normal, log-normal and Gumbel methods used in the estimations made for the Akçay stream are close to each other.

4-) It is understood from Figure 2 that the R^2 of the normal distribution is found 0,9187, from Figure 3 that the R^2 of the log-normal distribution is found 0,9350, from Figure 4 that the R^2 of the Gumbel distribution is found 0,8838. Since log-normal distribution R^2 is 93,5 %, the most suitable distribution is log-normal distribution.

5-) Since Akçay's mean flow and basin is small, a 100-year flood forecast has been chosen instead of the 250-year flood forecast. Consequently Akçay flow 7,52 m^3/s is chosen.

5. CONCLUSIONS

Statistical methods are widely used in frequency analysis of rivers. Possible flood discharges can also be calculated by using statistical methods. Flood discharges are very important for designing of the river structures. Due to fact that, flood discharges of Akçay play an important role for water resources planning in stream.

The flood forecast for different time periods is found. Since Akçay's basin area is small, 100 years of flood is preferred instead of 250 years of flood. However, possible flood discharge period, depending on economic conditions and the condition of the river structures can be varied.

The best result is found using log-normal distribution. However, other distribution functions can be used in future studies.

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