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# Comparison of flood discharge calculated by different statistical distribution functions and software

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## Abstract

Flood discharges can be calculated by using the river gauging (flow observation) station data and the rain gauge (precipitation observation) station data. In this study, both of the data set were evaluated to detect flood discharges of Kocaırmak (Bartın) River and the results were correlated each other. Firstly, the possible flood discharges were calculated by using different statistical distribution functions in Model 1 taking into account flow data of Kocaırmak (Bartın) River. Secondly, in Model 2, calculations were made with the help of different maps and different methods based on the data of rain gauge stations using software. In Model 1, as a result of calculations made with Normal, Log Normal, Gumbel and Pearson distributions functions, the flood discharges according to 50 years return period were determined as 926, 1579, 1128, and 1024 $m^3$/sec, respectively. The calculations made with the help of DSI and Mockus methods using the 1/25000 scaled digitized topographic maps and Aster-GDEM images with 30x30 m resolution in Model 2, the flood discharges according to 50 years return period were calculated as 999, 1305, and 1033, 1332 $m^3$/sec, respectively. By comparing the results obtained from models, it was found that the values obtained by Pearson distribution from Model 1 and the values obtained by DSI Synthetic Method from Model 2 were correlated well with each other.

**Keywords:** Flood Analysis, Statistical Distribution Functions, Mockus and DSI Synthetic Methods, Kocaırmak (Bartın) River

## 1. Introduction

Flood is a natural occurrence, which greatly affects the livelihoods all over the world. Designing of flood protection structures, to make flood discharge calculations and predictions with the appropriate methods have technological as well as societal important. Poor watershed management practices in the unplanned urbanizing scenario are also causes



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the induced flooding issues. Identification of effective methods for estimating flood discharges is crucial, especially in the perspective of uncertainties in the climate factors. Flood related studies are gaining greater importance regarding water resource development and management, flood protection, construction of storage structures, and hydrologic investigations (Jarosiska and Pierzga, 2015). The accuracy of these investigations and its execution is critically governed by the techniques adapted and the availability of long term data sets. Management of water sheds without periodical investigation of peak flow discharges is highly impossible (Ogunlela and Kasali, 2002; Boughton and Droop, 2003; Bhadra et al, 2008; Bhunya et al, 2011; Singh and Singh, 2017). The advancement in flood assessment methodologies have proven as effective especially in rainfall–runoff models to evaluate the hydrological characteristics of storm events which prevents the risks of flood hazards (Yonatan et al, 2009). Lack of precision in the determination of rainfall and the sophisticated data collection tools increase the complexity in assessing flood characteristics in catchments (Patrick et al, 2002). Recently, application of models to predict rainfall–runoff processes to assess flood properties is considered as well-known technology which also requires advancement and ease of applicability. A number of studies have been conducted to employ the statistical models, hydrographs and remote sensing and geospatial techniques for determining spatial and temporal analysis of peak flood discharge of different basins (Islam and Sado, 2000; Lopez et al, 2005; Aron and White, 2007; Salami et al, 2009; Dastorani et al, 2010; Singh, 2018; Özcan, 2017; Taş et al, 2016).

Floods, which can be natural or anthropogenic due to various factors such as global warming, urbanization are among the disasters that have caused the greatest loss of lives and property in recent years. Estimation of the flood discharge can be determined by using the data of the flow or rainfall. In the rainfall analyses, it is first necessary to model the basins using topographic maps and Aster images, etc. In the recent period, flood forecasting can be done by using methods such as Regional Analysis, Empirical Methods (Envelope Curves, Rational, Soil Conservation Services, DSI Synthetic, Mockus, etc.) and Hydraulic Methods.

In the present study, it is aimed to determine the possible flood discharge of 5, 10, 50, 100, 500 and 1000 years of recurrence intervals by using different data and methods and to analyze the efficacy of analysis methods. The study area of Kocaırmak (Bartın) River is selected for assessing the flood discharge with the available input data sets. The River is located in the Western Black Sea Region and drains the Bartın province and its vicinity (Figure 1). After the river joins with Kozcağız River coming from the south, it flows into the Black Sea. From the earlier studies, it is inferred that many flood disasters have occurred in the basin. The Bartın River Basin has a catchment area of approximately 2200 $km^2$ (Keskin, 2011, 2013) and the drainage area of the section (Kocaırmak) up to the current observation station E13A031 is approximately 1380 $km^2$ (Figure 2).

## 2. Meterial and Method

In this study, two different models were studied. Firstly, the flood calculation was made by using the maximum annual discharge by collecting the data set obtained from river gauging stations (E13A031) during 1970-2016 in the Model 1. In this model (Model 1), possible flood discharge for 5, 10, 50, 100, 500, and 1000 years of recurrence were calculated by using the Normal, Gumbel, Log-Normal and Pearson statistical distribution methods. Secondly, flood calculation was carried out by using daily maximum precipitation data obtained from precipitation observation stations around Kozcağız (Bartın) River basin and inputs were used in Nethydro module for developing flood models at NetCAD software (Model 2). This module is derived in recent years. In this model, basin modeling, precipitation analysis and flood analysis were performed. Two separate maps/images were utilized to model the basin. In this context, the 1/25000 scaled digitized topographic maps (Model 2.a), and Aster-GDEM (Model 2.b) images, which have 30x30 m resolution, developed jointly by Japan's Ministry of Economy, Trade and Industry (METI) and the United States National Aeronautics and Space Administration (NASA) were preferred. The daily maximum precipitation data of the Bartın, Cide, Karabük and Amasra precipitation observation stations with 15 years of continuous data in the vicinity of the Bartın (Kocaırmak) River Basin were used for the analysis of precipitation (DMI, 2018). The DSI Synthetic and Mockus methods were applied in the Nethydro module to determine the possible flood discharge for the recurrence periods of 5, 10, 50, 100, 500, and 1000 years and the outputs were compared with model 1. For flood analysis, flow curve number (CN) was chosen as 80 by considering the hydrogeological structure of the region, land terrain features and land use maps (Chow, 1964; SCS, 1972, 1989; Mishra and Singh, 2003; Bayazıt, 2003).

## 3. Analysis and Results

In Model 1, the flood discharges of the study area were found using flow data as inputs by conducting statistical analysis of Normal, Log-Normal, Gumbel and Pearson distribution functions which are commonly using in flood hydrology (Bedient and Huber, 1988; Chow et al. 1988; Linsey et al, 1988; McCuen, 1988). As a seen at Table 1, the flood discharge expected to be 649.36, 749.21, 925.66, 987.38, 1108.38, and 1152.62 $m^3$/sec with the Normal distribution function for the recurrence interval of 5,10,50,100,500, and 1000, respectively, while with the Gumbel distribution function estimated as 713.62, 983.83, 1578.53, 1829.95, 2410.92, and 2660.69 $m^3$/sec. Also, the discharges expected to be 618.54, 768.79, 1127.63, 1289.31, 1676.65, and 1845.66 $m^3$/sec with the Log-Normal distribution, while with the Pearson distribution function is estimated as 632.94, 761.05, 1024.40, 1128.36, 1351.05, and 1438.94 $m^3$/sec.

In model 2, hydro module of NetCAD was prefered. The program has long term maximum daily precipitation data required to determine the flood return periods. The drainage area modelling, rainfall analysis and flood analysis were carried out respectively in this model. The basin was modeled according to TauDEM algorithm in accordance with D8 flow model with the help of 49 1/25000 scaled topographic maps and 2 ASTER imageries. The algorithm of software was developed by Utah State University (USU) for hydrologic digital elevation model analysis and watershed delineation. the areas of basin from the topographical maps and imageries, respectively were obtained as 1378.2 $km^2$ and 1380.3 $km^2$. The spatial distribution of the point precipitation data of the stations was calculated according to Thiessen polygon method. Six different statistical distributions such as Normal, Log-Normal (with 2 parameters), Log-Normal (with 3 parameters), Pearson Type-3 (Gamma Type-3), Log-Pearson Type-3, Gumbel distributions were applied to rainfall data and the most appropriate results have been selected due to the Kolmogorov-Smirnov conformity test (Table 2). The modelled basin areas, flow networks and effective precipitation monitoring stations are given in Figure 2. As a result of the analysis, the possible flood discharge of 5, 10, 50, 100, 500 and 1000 years of recurrence intervals were obtained for the 2, 4, 6, 8, 12, 18, and 24 hours rainfall repetitions (Table 1). These optimized data sets were used for generating DSI Synthetic and Mockus flood flow models.

In the flood analysis, the harmonic slope, which is the basic input data in the calculation of the unit hydrograph parameters, was calculated over 50 pieces and the average was determined as 0.006. For flood analysis using DSI Synthetic and Mockus method, the pluviograph coefficient data of Bartın station which has the largest representation ratio in the basin was used. The analysis in the Mockus unit hydrograph method was made for both the 0.208 and 0.163 basin coefficients (K).

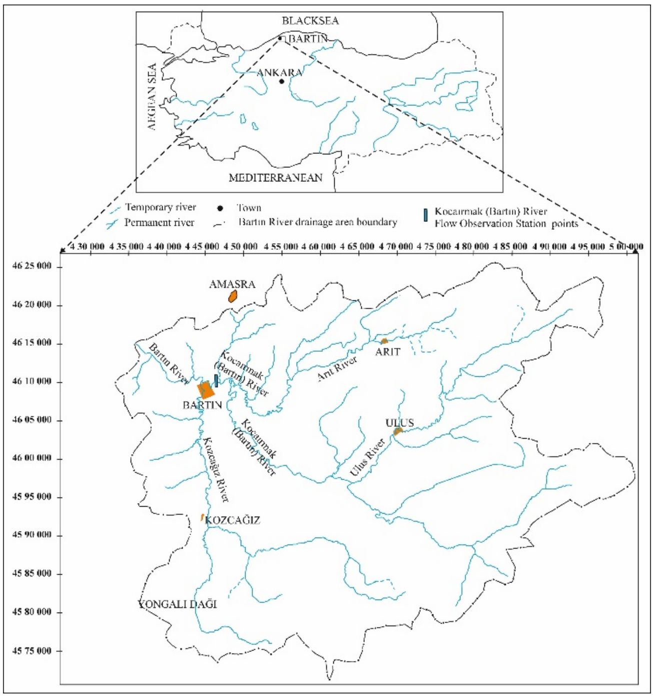


**Figure 1.** The location maps of the study area

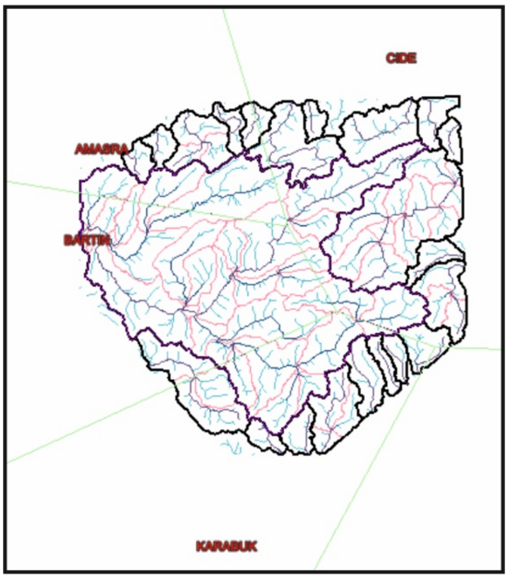


**Figure 2.** The modelled basin areas, flow networks and effective precipitation monitoring stations

**Table 1.** The flood discharge results ($m^3$/sec) obtained by using different methods of Kocaırmak (Bartın) River.

| Method | 5 | 10 | 50 | 100 | 500 | 1000 |
|---|---|---|---|---|---|---|
| **Model 1_Normal** | 649.4 | 749.2 | 925.7 | 987.4 | 1108.4 | 1152.6 |
| **Model 1_Gumbel** | 713.6 | 983.8 | 1578.5 | 1830.0 | 2410.9 | 2660.7 |
| **Model 1_Log-Normal** | 618.5 | 768.8 | 1127.6 | 1289.3 | 1676.7 | 1845.7 |
| **Model 1_Pearson** | 632.9 | 761.1 | 1024.4 | 1128.4 | 1351.1 | 1438.9 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Model 2. a_DSI Synthetic** | 632.4 | 761.7 | 999.0 | 1085.5 | 1309.5 | 1406.0 |
| **Model 2. a_Mockus (K=0.208)** | 683.5 | 873.0 | 1305.4 | 1497.8 | 1930.1 | 2116.3 |
| **Model 2. b_DSI Synthetic** | 653.2 | 787.1 | 1032.9 | 1122.2 | 1354.2 | 1454.0 |
| **Model 2. b_Mockus (K=0.208)** | 696.9 | 890.3 | 1331.5 | 1527.9 | 1969.1 | 2159.1 |

**Table 2**. Data of rainfall stations and optimum distribution results in different repetition intervals.

| Station Name | Simirnov-Kolmogorov | Station Ratio | 5 | 10 | 50 | 100 | 500 |
|---|---|---|---|---|---|---|---|
| Bartın | Normal | 0.51 | 91.67 | 102.60 | 121.78 | 128.55 | 142.17 |
| Cide | Log Normal (3 Parameters) | 0.19 | 93.58 | 112.76 | 160.67 | 183.34 | 241.23 |
| Karabük | Log-Pearson Type-3 | 0.16 | 42.41 | 51.34 | 74.81 | 86.56 | 114.37 |
| Amasra | Gumbel | 0.15 | 73.35 | 83.20 | 104.86 | 114.02 | 135.19 |

Table 1 show that the flood discharge results (m3/sec) obtained by using different methods of Kocaırmak (Bartın) River. As a result of the calculation made by DSI Synthetic method using 1/25000 scaled digitized topographic maps, the predicted flood discharges according to the repetitions of 5, 10, 50, 100, 500 and 1000 years, were estimated as 632.4, 761.7, 999.0, 1085.5, 1309.5, and 1406.0 $m^3$/sec respectively. Also as a result of the calculation made by Mockus method (for the basin coefficients (K)- 0.208) using 1/25000 scaled digitized topographic maps, the flood discharges were predicted as 683.5, 873.0, 1305.4, 1497.8, 1930.1, and 2116.3 $m^3$/sec. Furthermore, the predicted flood discharges using Aster-GDEM images, according to DSI Synthetic method were calculated as 653.2, 787.1, 1032.9, 1122.2, 1354.2, and 1454.0 $m^3$/sec. Also according to Mockus method the flood discharge using Aster-GDEM images were detected as 696.9, 890.3, 1331.5, 1527.9, 1969.1, and 2159.1 $m^3$/sec.

Also, as a result of the calculation made by Mockus method for 0.163 basin coefficient (K) using 1/25000 scaled digitized topographic maps, the predicted flood discharges were determined as 535.6, 684.1, 1022.9, 1173.7,1512.6, and 1658.5 m3/sec. Using Aster-GDEM images for 0.163 K coefficient, the predicted vales were 546.2, 697.7, 1043.4, 1197.3, 1543.1, and 1692.0 m3/sec. From the these analysis, it is found that 0.208 basin coefficient used in the Mockus method was more compatible with the other methods. The 0.163 basin coefficient yielded very low flood values for both Aster-GDEM images and digitized topographic maps when compared to the 0.208 basin coefficient.

## 4. Evaluation and Discussions

In this study, flow data was considered in Model 1, while rainfall data was considered in Model 2, and flood discharges were calculated according to the repetitions of 5, 10, 50, 100, 500 and 1000 years by using different methods. In Model 1, the Normal distribution, Gumbel distribution, Log Normal distribution and Pearson distribution functions were applied using the annual maximum flow data of the E13A031 flow gauging station located near the city center of Bartın River and the flood discharges of 100 years were calculated as 987, 1830, 1289, and 1128 m3/sec, respectively. In Model 2, precipitation data from Bartın, Cide, Karabük and Amasra observation stations were used to determine flood discharges by using DSI Synthetic and Mockus methods with the help of 1/25000 scaled digitized topographic maps and Aster-GDEM images. In the analysis, the flow curve number (CN) was selected as 80 depending on the hydrogeological structure of the region and land use maps. Accordingly, the flood discharges of 100 years return period were calculated as 1085 m3/sec and 1498 m3/sec (for the 0.208 basin coefficient) using DSI and Mockus methods respectively. It can be understood that, 0.208 basin coefficient used in the Mockus method was more compatible with the other methods. The basin coefficient of 0.163 yielded very low flood values.

By comparing the results obtained from Model 1 (for discharge data) and Model 2 (for rain data), it was found that values obtained by Pearson distribution from Model 1 and the values obtained by DSI Synthetic method from Model

2 were very close to each other. This results shows that if the accurate flow curve number (CN) according to the land use and hydrogeology properties is selected, the long term rainfall data is well adequate to provide reliable results. This will be very beneficial for calculating flood flows in regions with the absence of flow monitoring station or in the ungauged data scarce regions. In addition, the study reveals the utility of flood modeling using NetCAD as one of the convenient and efficient techniques for watershed development and management studies. The study proved that the models generated by using the flow curve number and rainfall data could represent the reliable basin flow characteristics for the selected Kocaırmak (Bartın) River system.

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