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Flood Discharge Estimation by Synthetic Methods

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ABSTRACT

Floods affect humanlife through ecological, financial and social factors. Therefore, it is quite important to observe and record flood discharges when possible. In case no measurements are available, flood discharges can be estimated by synthetic methods for any given return period. There are however, some limitations of synthetic methods considered. Well known methods are Snyder, Synthetic SCS, and Mockus among many others widely used to estimate flood hydrograph. Also, the rational method can be used to estimate the flood discharge in drainage areas smaller than 1 km^2. For derivation of a synthetic hydrograph, the drainage area, hydrograph rising limb and concentration time of the basin are needed. In this study, Tacin River, a subbasin in Seyhan River Basin, southern Anatolia, Turkey, is selected as study area. Seyhan River Basin is of great agricultural importance for the country. The subbasin has 9.9 km^2 drainage area. An observation longer than 50 years is available. The Mockus method is selected as the synthetic unit hydrograph method because of its suitability to watersheds at the range of 1-10 km^2 drainage area. Geographic Information Systems (GIS) are widely used in hydrological modeling studies due to the fact that estimation of extreme events linked to morphology is not an easy task. Morphological characteristics are calculated in the Mockus method using the recent Multi-Error-Removed Improved-Terrain (MERIT) DEM data which are more accurately developed from the Shuttle Radar Topography Mission (SRTM). The calculated and observed flood discharges are compared. It is expected that such a study will guide hydrological studies in Seyhan River Basin.

Keywords: Flood, Mockus Synthetic Unit Hydrograph, Morphological Characteristics, Seyhan River Basin, Turkey.

1. INTRODUCTION

Flood is one of the most important disaster of the extreme events. It is easily affected by rainfall and snowmelt. In addition, morphological characteristics of a basin are effective parameters on flood event. Although it is important to determine flood discharge, it is even more important to obtain flood hydrographs. In this way, flood hydrograph which has the elements as lag time, rising and recession limbs, and baseflow, provides important information to determine flood water volume and then the boundary of the flooded area.

Flood hydrographs are produced in practice by synthetic methods. The common methods are Snyder, Soil Conservation Service (SCS) and Mockus. There are however, some limitations of each synthetic method. The Snyder method is used for basins which have bigger than 1000 km^2 drainage area. The SCS method is used for basins which have between 10 and 1000 km^2 drainage area. Finally, the Mockus method is used for basins which have a drainage area of 1-10 km^2. It is difficult to define a flood hydrograph for basins which have a drainage area smaller than 1 km^2 because of short concentration time. For smaller basins, flood discharge can be calculated by Rational method which is based on the basin characteristics. The characteristics are the drainage area, rainfall intensity corresponding to any return period and runoff coefficient which is a function of soil type and drainage basin slope. Nowadays, the basin characteristics can be calculated by Geographical Information System (GIS)-based softwares.

The advances in GIS technologies have led to its widespread use in studies based on the improvement of hydrology and water resources. In this study, the newly developed and freely available Multi-Error-Removed Improved-Terrain (MERIT) Digital Elevation Model (DEM) is used as the topographical data. The data has 3 s-resolution with more accuracy than the Shuttle Radar Topography Mission (SRTM) DEM data by taking into consideration also the height of the trees (Yamazaki *et al*. 2017).

In this study, the watershed characteristics of Tacin River are calculated in ArcHydro module which is integrated with ArcGIS software. The concentration time and flood peak discharge are calculated from the watershed characteristics. The triangular unit hydrograph is computed by the Mockus method. At the end, the calculated flood peak discharges are compared with the observed flood peak discharges from the gauging station.

2. METHOD

Hydrograph is a graph that represents discharge versus time. It can be produced from observed data of gauging station. The Mockus method was selected to produce flood hydrograph of Tacin watershed. First, the unit hydrograph was produced. The flood peak discharges were then calculated with maximum rainfall corresponding any return period. The unit hydrograph is the direct runoff hydrograph produced by a storm of a given duration, such that the total volume of excess rainfall (=direct runoff) is 1 mm (Chow *et al.* 1988).

The Mockus method is expressed as follows (Istanbulluoglu *et al*. 2004):

$$T_c = 0.00032 \frac{L^{0.77}}{S^{0.385}} \quad (1)$$

T_c is the time of concentration of the watershed (in hour), L is the length of the main stream from the outlet to the upstream divide (in m), S is the slope that is equal to $\Delta h/L$ where Δh is the difference in elevation between the most remote point in the watershed and the outlet (in m).

$$t_p = 0.6T_c \quad (2)$$

t_p is the watershed lag (in hour).

$$t_r = 2\sqrt{T_c} \quad (3)$$

t_r is the duration of the rainfall excess (in hour).

$$T_p = \sqrt{T_c} + 0.6\sqrt{T_c} \quad (4)$$

T_p is the time to peak runoff unit hydrograph (in hour).

$$T_r = HT_p \quad (5)$$

T_r is the recession time, time from the peak to the end of surface runoff (in hour), H is a coefficient representing watershed characteristics.

$$T_b = T_p + T_r \quad (6)$$

T_b is the time base, time from the beginning to the end of surface runoff (in hour).

$$q_p = K\frac{A}{T_p} \quad (7)$$

q_p is the peak discharge per unit of watershed (in m^3/s/mm), K is a coefficient, A is the watershed area (in km^2).

$$Q_{p,T} = q_p h_a \quad (8)$$

$Q_{p,T}$ represents flood peak discharge which is acquired by multiplying excess rainfall depth (h_a, in mm) corresponding any return period (T, in year).

Calculated peak discharges were compared by observed flood peak discharges from gauging station. For this aim, frequency analysis was applied to 48-year observed annual peak discharges. After the selection of the best-fit distribution, peak discharges were calculated using the probability distribution function.

3. STUDY AREA AND DATA

Tacin River, a subbasin in Seyhan River Basin, in southern Anatolia, Turkey, was selected as study area (Figure 1). Seyhan Basin which has 20450 km^2 drainage area is of great agricultural importance for the country (Burgan and Aksoy 2018). The outlet of Tacin River subbasin is located on 36°04'44"

E - 38°49'52" N geographic coordinates. The subbasin has 9.9 km^2 drainage area. An observation longer than 50 years is available. The characteristics of the subbasin are presented in Table 1.

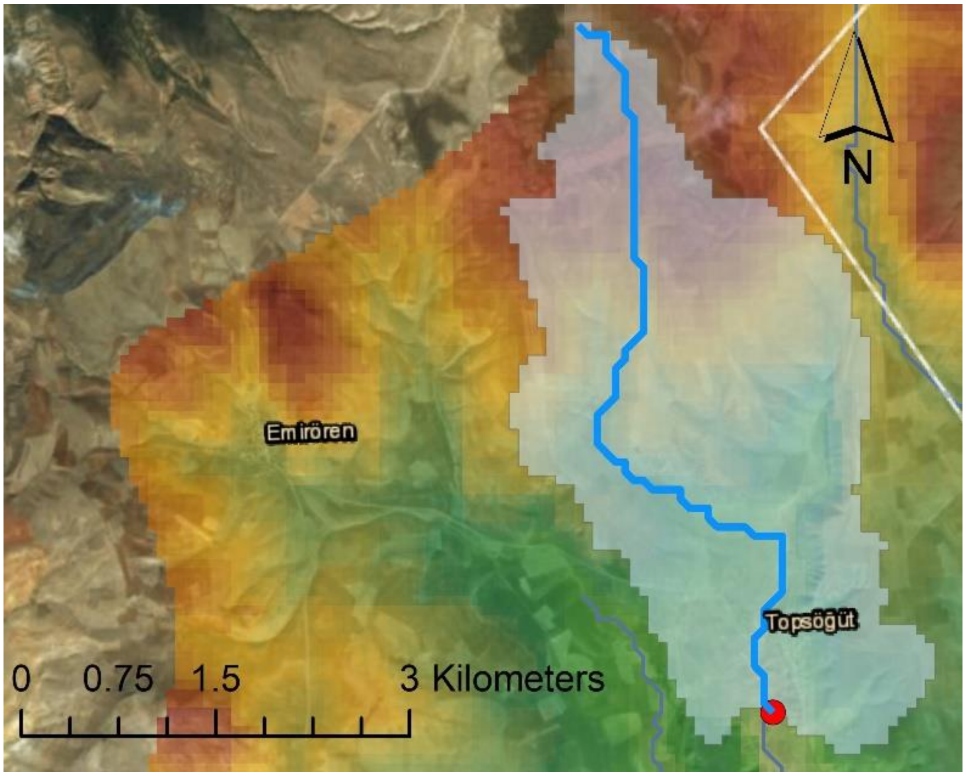

Figure 1. Tacin River and its subbasin

Table 1. The characteristics of the Tacin River subbasin

Drainage Area (km^2)	9.9
Elevation (m)	1536
Latitude-Longitude	36°04'44" E - 38°49'52"
Observation Period	1965-2014 (48 years)
Channel Length (km)	7.019
Channel Slope	0.0516

Three types of data were used in the study. The morphological data was produced from MERIT data in ArcGIS software. The annual peak discharge data was provided by State Hydraulic Works (DSI). The annual maximum precipitation rainfall data was obtained from General Directorate of Meteorology (MGM). The observation period for precipitation data is 1984-1998 (14 years).

4. RESULTS

The calculated parameters by Mockus method are demonstrated in Table 2 in which the H and K coefficients were selected as 2.15 and 0.341 (the maximum values for Anatolia), respectively (Istanbulluoglu 2004). The triangular unit hydrograph of the basin was produced by applying the Mockus method (Figure 2). The area represented by each meteorological station was calculated by the Thiessen method.

Table 2. The calculated parameters by Mockus method

	Parameters (hour)
T_c	0.917
t_p	0.550
t_r	1.915
T_p	1.532
T_r	3.241
T_b	4.749

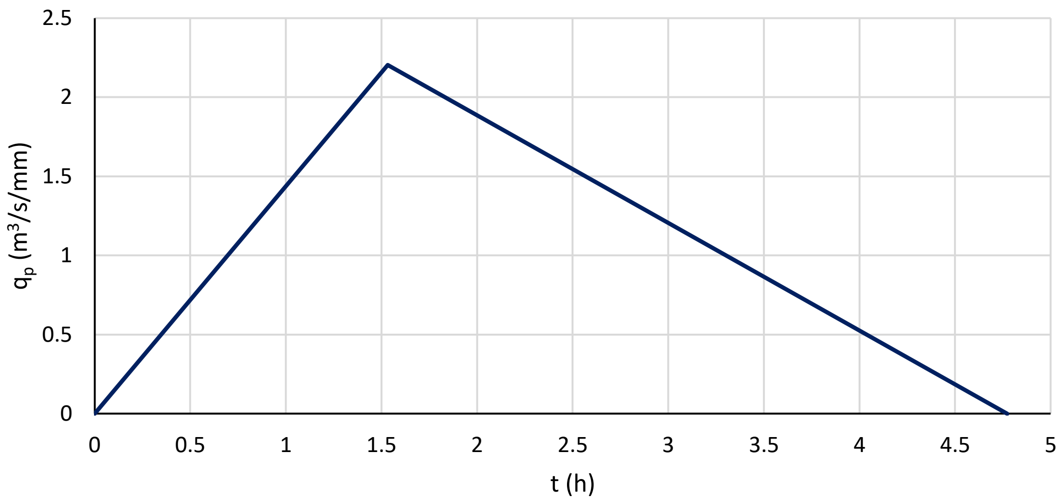

Figure 2. The triangular unit hydrograph of the basin

The frequency analysis was applied for precipitation data. The Generalized Extreme Value (GEV) distribution was found the best for the data according to the Anderson-Darling test. The flood peak discharges corresponding to return periods of 2, 5, 10, 25, 50, 100 years were calculated from Eq. (8).

The frequency analysis was also applied for the observed annual peak discharges. The best-fit distribution for the annual peak discharges was found to be the GEV distribution according to the Anderson-Darling test. The flood peak discharges calculated after the frequency analysis are compared with the Mockus method in Figure 3. It is seen that the Mockus method provides quite higher peaks discharges as in Table 3. The reason for the overestimation could be because of the selection of the upper limits of the selected H and K coefficients.

Table 3. Peak discharges observed and calculated by the Mockus method

Return Period (year)	Peak Discharge (m^3/s) Observed	Calculated	Relative Error (%)
2	2.083	2.256	8
5	2.505	2.937	17
10	2.699	3.266	21
25	2.875	3.580	25
50	2.970	3.757	26
100	3.042	3.896	28

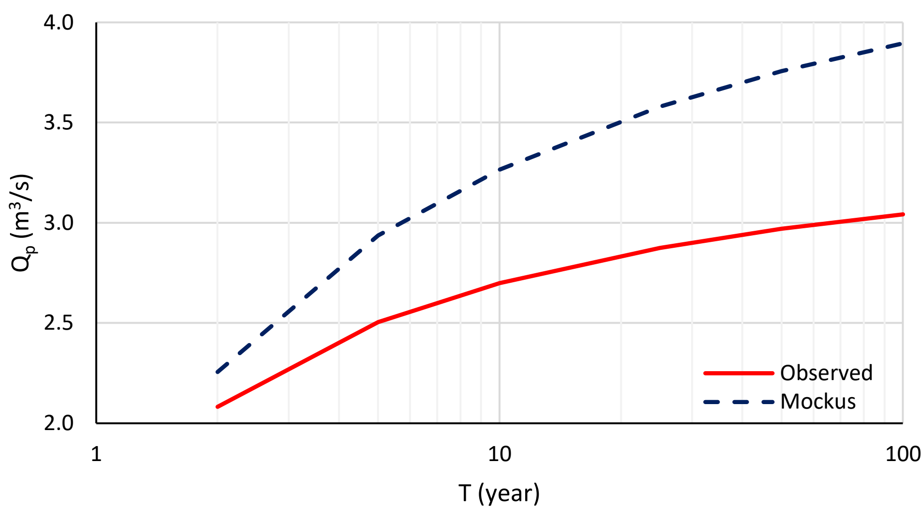

Figure 3. Flood peak discharges calculated after the frequency analysis and by the Mockus method

5. CONCLUSION

The flood discharges corresponding to any return period can be estimated from observed data of gauging stations using frequency analysis. Synthetic methods are also widely used when no data exist in the ungauged basin case. In this study, the watershed characteristics are calculated using the recently developed MERIT topographical data. The Mockus synthetic unit hydrograph method is used for the case study. Results show that the peak discharges are estimated lower than the observation within an acceptable range of 8-30% relative error. Besides, the Mockus methods overestimates the peak discharges for all return periods. It gives a safety to the design when the overestimation is within an acceptable range.

REFERENCES

Burgan, H. I., Aksoy, H. (2018). Annual flow duration curve model for ungauged basins, *Hydrol. Res.*,4 9(5), 1684-1695.

Chow, V. T., Maidment, D. R., Mays, L. W. (1988). *Applied Hydrology*. McGraw-Hill, New York.

Istanbulluoglu, A., Konukcu, F., Kocaman, I. (2004). Precise determination of turkish spillway sizes from synthetic unit hydrographs to prevent flood damage. *Acta Agr. Scand. B-S. P.*, 54(3), 114-120.

Yamazaki, D., Ikeshima, D., Tawatari, R., Yamaguchi, T., O'Loughlin, F., Neal, J. C., Sampson, C. C., Kanae, S., Bates, P. D. (2017). A high-accuracy map of global terrain elevations. *Geophys. Res. Lett.*, 44(11), 5844-5853.