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RESEARCH ARTICLE

Trend analysis of mean monthly, seasonally and annual streamflow of Daday Stream in Kastamonu, Turkey.

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ABSTRACT

Water is one of the most important natural resources and assessment of the trends in water has a great importance to estimate the future of water resources. The main purpose of this study is to present a trend analysis of the streamflow of Daday Stream in Kastamonu, Turkey by monthly, seasonally and annual analyses. Monthly streamflow data were obtained from streamflow gauging station on the stream between 1988 and 2007. Trends of monthly, seasonal and annual runoff of Daday Stream were analysed by Trend analysis, non-parametric Mann-Kendall and Spearman tests. The results showed that mean annual streamflow of Daday Stream had a significant tendency to decrease for this period ($p<0.01$). The results of seasonal trend analysis results demonstrated that statistically significant decreasing trends were found for all seasons. Trend analyses for monthly mean streamflow displayed that there were also statistically significant decreasing trends for all month excluding February, March, April, and June. In conclusion, decreasing trends in the streamflow of Daday Stream have been predicted for this period and for the future. The fluctuation in water resources could be affected by some reasons such as decreasing rainfall, rising temperature depending upon climate change.

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Introduction

Water is one of the most important natural resources and many studies focused on water to investigate the temporal variations or characteristics of water with different purposes around the world. The Intergovernmental Panel on Climate Change (IPCC, 2007) noted that water resources are under pressure and stress by some reasons such as growing population, greenhouse gases, temporal variations, climate change, and other reasons for half a century. Interactions between climatic parameters and topography, vegetation, and soil affecting evaporation, precipitation, and infiltration define the streamflow (Dingman, 2002; Brutsaert, 2005). These processes and the regime of the streamflow are commonly estimated to be affected by the climate change (Zhou et al., 2014; Christensen et al., 2004; Stewart et al., 2004).

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The temporal patterns of streamflow is sensitive to the climate change. The impacts of the climate change on the hydrologic processes in rivers are widely accepted by many authors. A few scientists have investigated the projected effects of climate change on streamflows at a regional scale (Christensen et al., 2004; Stewart et al., 2004; Reidy and Liermann et al., 2012). Current trends of the streamflows should be determined and monitored, and future trends should also be predicted to understand the possible effects of the climate change. Assessment of the trends in water parameters has a great importance to estimate the future of water resources. Therefore, investigations on the trend of water resources and rivers provide valuable contributions to the knowledge for the water resources management and decision-making process.

Several authors have analysed trends in climatic and hydrologic parameters (Kadıoğlu, 1997; Büyükyıldız and Berktay, 2004; Şensoy et al., 2005; Cigizoglu et al., 2005; Yıldırım et al., 2013; Saplıoğlu et al., 2014; Sütgibi, 2015; Yenigün and Ülgen, 2016; Ay and Özyıldırım, 2017; Ercan and Yüce, 2017; Tosunoğlu, 2017; Tosunoglu and Kisi, 2017). Also numerous studies determined trends in water parameters by using different methods (Sen, 1968; Hirsch et al., 1982; Helsel and Hirsch, 2002; Şen, 2012). In Turkey, trend analysis for water parameters were firstly carried out by İçağa (1994). Afterwards, many authors conducted studies to estimate the trends in water parameter (İçağa and Harmancıoğlu, 1995; Kalayci and Kahya, 1998; Albek, 2002; Kişi and Ay, 2014; Doğan Demir et al., 2016; Ejder et al., 2016a, 2016b; Kale et al., 2016a, 2016b; Kişi et al., 2018; Kale et al., 2018). Unfortunately, there is no study on determining and monitoring trends of the streamflow of Daday Stream. Therefore, the main purpose of this study is to present a trend analysis of the streamflow of Daday Stream in Kastamonu, Turkey.

Material and Methods

Study Area

Daday Stream arises from Çamlıbel village and runs through the villages of Akılçalman, Örencik, Akpınar, Bolatlar, Tüfekçi, Sarıçam, Yazıcameydan, İnciğez, Kızılörencik, Eymir, Hacımuharrem, Talipler, Çiğil, Dokuzkat, Göcen, Subaşı, Numanlar, Gölköy, Emirler, Sarıömer, Koruköy, Hocaköy, Mollaköy, Kurtgömeç, Hasköy, Kurusaray, Emirli, Hatipköy, Eşenköy and the city centre of Daday district and Kastamonu province (Figure 1). It merges with Karasu Stream in Bükköy as tributaries of Gökırmak Stream. The climate of the region is typical continental climate with snowy winters, warm summers in drier conditions, and spring and autumn seasons that are often sharp cold and frost which is unfavourable for agriculture and production of vegetables and fruits. Daday Stream rises from 1217 km and its length is calculated 72.3 km.

Streamflow data were obtained from streamflow gauging station at Hasköy (D15A225) of the General Directorate of State Hydraulic Works (DSİ). Analyses were carried out for each of mean monthly, seasonal, and annual data.

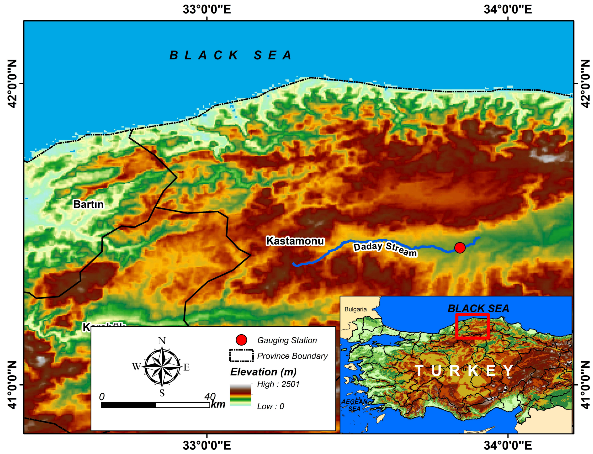

Figure 1. The location of Daday Stream.

Change Point Analysis

Pettitt's change-point analysis (Pettitt, 1979) was used to detect the change time of the streamflow data. This non-parametric test was modified from the Mann-Whitney statistic and detects significant changes in the averages of time series. Pettitt's change-point analysis was performed in R statistical software (R Core Team, 2017). The formulae as follow:

$$U_{t,T} = \sum_{i=1}^{t}\sum_{j=t+1}^{T} sgn(x_i - x_j) \text{ for } t = 2,\ldots\ldots,T$$

$$K_T = max|U_{t,T}|,$$

The null hypothesis of the change-point test is the absence of change point. The statistic of null hypothesis is K_T. $U_{t,T}$, confirms whether two examples ($x_1,\ldots\ldots, x_t$ and $x_t+1,\ldots\ldots,x_T$) are in the same population or not. Associated probability (*p*) is used for computing the significance.

Trend Analysis

Trend analysis is commonly used method to determine the tendency in a hydrological time series. Box-Jenkins technique (Box and Jenkins, 1976) and the auto regressive integrated moving average model were applied to understand the trend of streamflow. In ARIMA model (*p, d, q*), *p* shows the number of auto regressive terms, *q* shows the number of moving average terms and *d* shows the differencing order. The ARIMA model used in the study as follow:

$$X_t = c + \Phi_1 X_{t-1} + \cdots + \Phi_p X_{t-p} + \theta_1 e_{t-1} + \theta_q e_{t-q} + e_t$$

In this equation, X_t is the variable will be described in *t* time, *c* is the constant, Φ is coefficient of per *p* parameter, θ is the coefficient of per *q* parameter, and e_t is the error in *t* time.

Mann-Kendall Test

Mann-Kendall test (Kendall, 1955; Mann, 1945) is a widely used test to explore the trends in a time series. Non-parametric Mann-Kendall test and Spearman's rho test offer more trustworthy results than parametric tests. One advantage of this non-parametric test is that the data do not require to track any specific distribution. The formulae for this test are as follows:

$$S = \sum_{i=1}^{n-1} \sum_{k=i+1}^{n} sgn(x_k - x_i)$$

In this equation, the time series x_i is from i = 1, 2, …, n-1, and x_k from $k = i$ + 1, …, n.

$$sgn(\theta) = \begin{cases} +1, & \theta > 0 \\ 0, & \theta = 0 \\ -1, & \theta = 0 \end{cases}$$

Normalized test statistic is computed by the follow equation:

$$Z_c = \begin{cases} \frac{S-1}{\sqrt{var(S)}}, & S > 0 \\ & S = 0 \\ \frac{S+1}{\sqrt{var(S)}}, & S < 0 \end{cases}$$

Z_c is the test statistic and when $|Z_c| > Z_{1-\alpha/2}$, in which $Z_{1-\alpha/2}$ are the standard normal variables and α is the significance level for the test, H_0 will be rejected. The magnitude of the trend is given as follow:

$$\beta = \text{Median}\left(\frac{x_i - x_j}{i-j}\right), \forall_j < i, \text{ where } 1 < j < i < n.$$

A negative value of β shows a decreasing trend, while a positive value of β shows an increasing trend.

Results

The descriptive statistics of the runoff data including mean with standard deviation, coefficient of variation (CV), coefficient of skewness, maximum and minimum values and range are listed in Table 1.

The results of change point analysis indicated that the change point for mean annual runoff was 1993. As a result of the trend analysis, a decreasing trend was found for mean annual runoff (Figure 2).

For mean seasonal runoff, change points were detected 1993, 1993, 1999, and 2002 for spring, summer, autumn, and winter, respectively. The results of trend analyses showed that runoff has decreasing trends for all seasons (Figure 3).

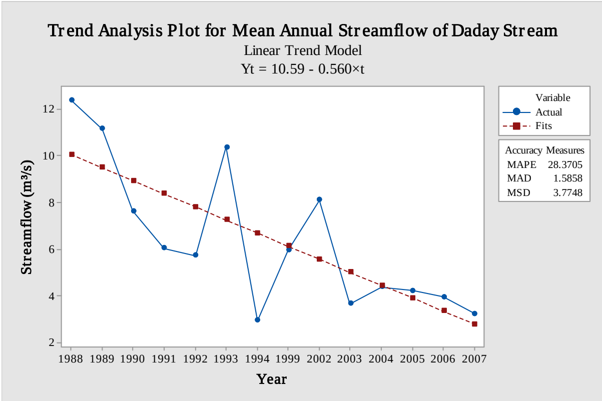

Figure 2. Trend analysis result of mean annual streamflow.

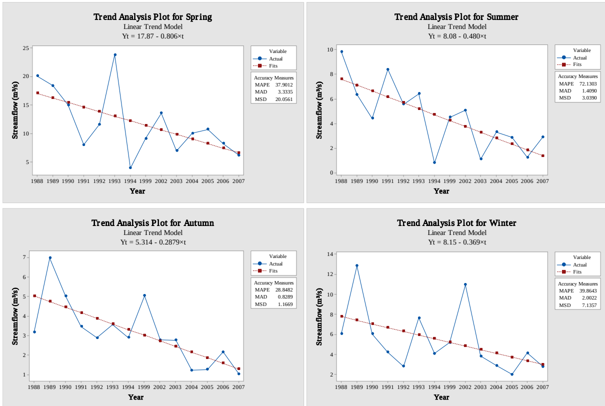

Figure 3. Trend analysis results of mean seasonal streamflow.

Change point analysis results detected the change point years for mean monthly runoff as 1999, 2002, 1993, 2004, 1993, 1993, 2002, 2002, 2002, 1999, 1999, and 2002 for the months from January to December, respectively. Trend analysis results showed that mean monthly runoff have decreasing trends for all months (Figure 4).

Results of Mann-Kendall trend tests pointed out that there is a statistically significant decreasing trend in the series of mean annual runoff (p<0.01). Also statistically significant decreasing trends were found for mean seasonal runoff for all seasons. Moreover, there were statistically significant decreasing trends for mean monthly runoff for all months excluding February, March, April, and June (Table 2).

Table 1. Basic statistics of streamflow data.

Mean Streamflow	Average	Standard deviation	Coefficient of variation	Coefficient of skewness	Maximum value	Minimum value	Range
Annual	6.40	3.09	0.48	0.56	12.38	2.91	9.47
Spring	11.83	5.74	0.49	0.77	23.87	3.91	19.96
Summer	4.48	2.70	0.60	0.04	9.84	0.78	9.06
Autumn	3.16	1.65	0.52	0.49	6.97	1.03	5.94
Winter	5.38	3.17	0.59	1.15	12.83	1.99	10.84

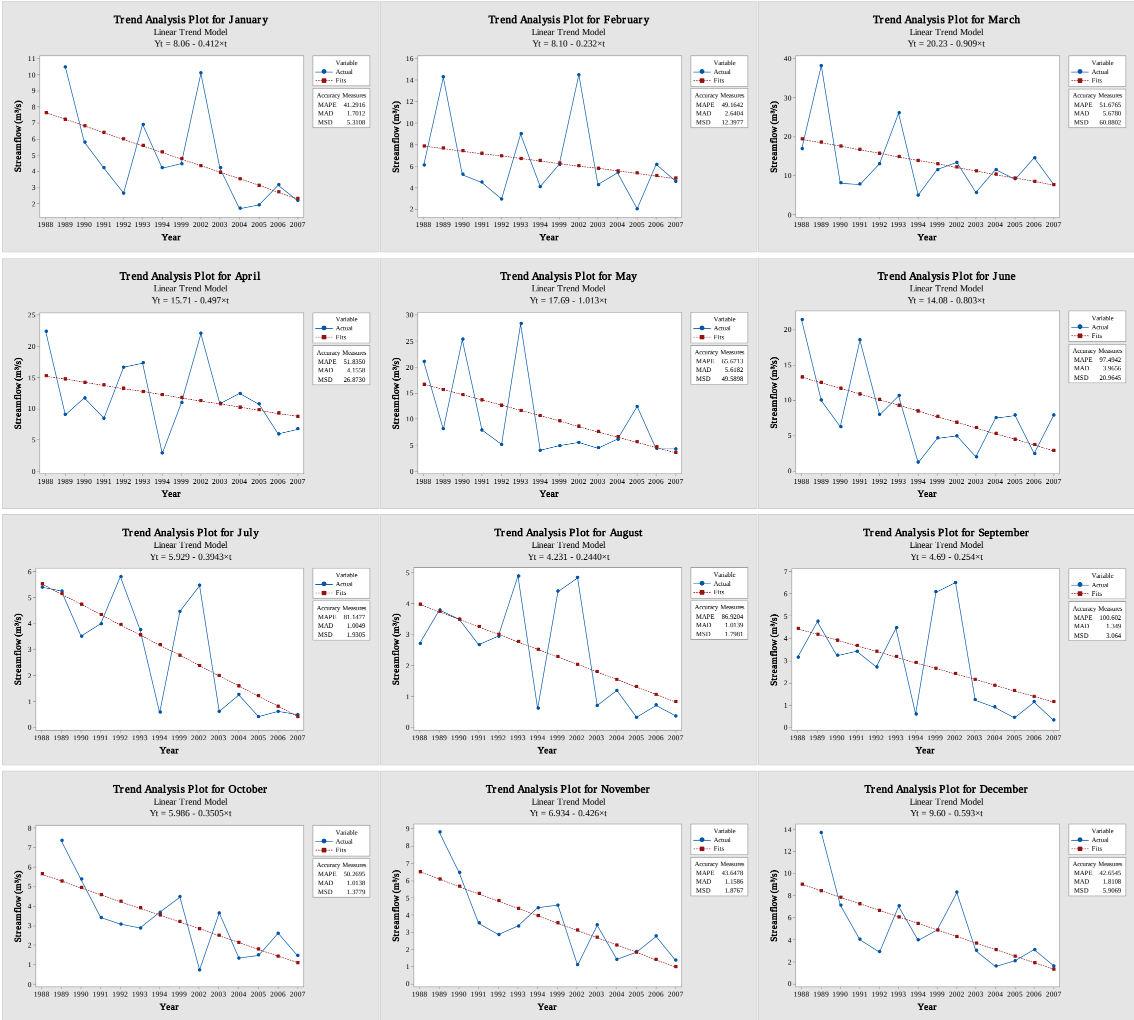

Figure 4. Trend analysis results of mean monthly streamflow.

Table 2. Non-parametric tests values and trend status.

Period	Streamflow	Kendall's tau	*p*	Trend	Spearman's rho	*p*	Trend
	Annual	-0.604	0.003	▼	-0.741	0.002	▼
Seasonally	Spring	-0.429	0.033	▼	-0.578	0.030	▼
	Summer	-0.516	0.010	▼	-0.710	0.004	▼
	Autumn	-0.648	0.001	▼	-0.815	0.000	▼
	Winter	-0.473	0.019	▼	-0.631	0.016	▼
Monthly	January	-0.452	0.032	▼	-0.644	0.018	▼
	February	-0.143	0.477		-0.178	0.543	
	March	-0.221	0.273		-0.339	0.236	
	April	-0.275	0.171		-0.376	0.185	
	May	-0.407	0.043	▼	-0.569	0.034	▼
	June	-0.319	0.112		-0.516	0.059	
	July	-0.486	0.016	▼	-0.664	0.010	▼
	August	-0.363	0.071	▼	-0.552	0.041	▼
	September	-0.385	0.055	▼	-0.569	0.034	▼
	October	-0.513	0.015	▼	-0.709	0.007	▼
	November	-0.538	0.010	▼	-0.753	0.003	▼
	December	-0.513	0.015	▼	-0.687	0.010	▼

Note: ▼ indicates statistically significant trends.

Discussion

Water resources are limited in the worldwide and several countries will face serious water shortages and/or scarcities on limited resources due to the impacts of global warming and climate change (Hisar et al., 2015). Therefore, investigations on the trend of water resources and rivers provide valuable contributions to the knowledge for the water resources management and decision-making process.

There are many studies about trend analysis on climatic parameters such as temperature (Türkeş et al., 1996; Han et al., 2012; Limjirakan and Limsakul, 2012; Doğan Demir and Demir, 2016; Demir et al., 2008; Duman and Kara, 2017; Kale, 2017a), evaporation (Tebakari et al., 2005; Jaswal et al., 2008; Kale, 2017b; Bacanlı and Tanrıkulu, 2017), and precipitation (Partal and Kahya, 2006; Aslantaş Bostan and Akyürek, 2007, 2010; Kızılelma et al., 2015; Doğan Demir and Demir, 2017; Yavuz and Erdoğan 2012; Bacanlı and Tanrıkulu, 2016; Bacanli, 2017; Taylan and Aydın, 2018). Trend analyses were also carried out to determine the trends in the streamflow. Numerous authors have reported decreasing trends in the streamflow of rivers. Durdu (2010) reported decreasing trend in Büyük Menderes River basin. Zhou et al. (2015) informed that there was a decrease in Huangfuchuan River streamflow. Herawati et al. (2015) found decreasing trend in streamflow of rivers in Indonesia. Pumo et al. (2016) stated that streamflow presented a significantly decreasing trend in non-perennial small rivers in Italy. Ozkul (2009) and Ozkul et al. (2008) informed about decreasing trends in the streamflow of Gediz and Büyük Menderes rivers. Türkeş and Acar Deniz (2011) described decreasing trend in the streamflow of the southern Marmara rivers. Bahadir (2011), Kahya and Kalaycı (2004), Koçman and Sütgibi (2012) reported that streamflow of rivers tended to decrease. Ejder et al. (2016a) described a decreasing trend in Sarıçay streamflow while Ejder et al. (2016b) documented a decreasing trend in the streamflow of Kocabaş Stream. Kale et al. (2016a) and Kale et al. (2016b) informed that decreasing trends were found in the streamflow of Karamenderes and Bakırçay rivers, respectively. Kişi et al. (2018) described decreasing and increasing trends in monthly streamflow of three different basins in Turkey. Kale et al. (2018) recently documented decreasing trends in rivers in western Turkey. Kale and Sönmez (2018) also reported decreasing trends in the streamflow of Akkaya Stream in Turkey and highlighted that decreasing trends were found statistically significant for mean annual, seasonal and monthly streamflow. Authors claimed that decreasing trend in the streamflow of Akkaya Stream could be attributed to decrease in rainfall and snowmelt, tremendously increase in temperature of air and water and other causes resulted from the climate change.

In this paper statistically significant decreasing trends were found for mean annual, seasonal, and monthly (excluding February, March, April, and June) streamflow. The findings of the present study are related to other reported trend analyses researches on hydrologic parameters. These decreasing trends could be related to the climate change especially rainfall and temperature. Changes in the climate such as rising temperature and decreasing rainfall may affect the streamflow and availability of water resources. On the other hand, Bates et al. (2008) stated that trends in streamflow were not always related to the variations in the precipitation. Some authors noticed that agricultural activities (Durdu, 2010; Dügel and Kazanci, 2004; Kaçan et al., 2007; Yercan et al., 2004), hydraulic structures (Ozkul et al., 2008) and human activities (Gao et al., 2011; Jackson et al., 2011; Zhou et al., 2015) had effects on the river streamflow along with the effects of the climate change.

Conclusion

Trends of monthly, seasonal and annual streamflow of Daday Stream were analysed. Statistically significant decreasing trends were found for mean annual, seasonal, and monthly streamflow excluding the months of February, March, April, and June. This study is the first study on determining and monitoring trends of the streamflow of Daday Stream. So, this paper provides significant information about past, current and future trends of the streamflow of Daday Stream. The amount of streamflow and water resources could be affected by some reasons such as decreasing rainfall, rising temperature depending upon climate change. In future period, it is predicted that decreasing trend will continue for Daday Stream. Therefore, available water resources should be effectively and efficiently managed. Sustainable use of water resources should be ensured to maintain the sustainability of natural resources.

Conflict of Interest

The authors declare that there is no conflict of interest.

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