Climate change effects on annual streamflow of Filyos River (Turkey)
Adem Yavuz Sönmez and Semih Kale

ABSTRACT
The main purpose of this study was to estimate possible climate change effects on the annual streamflow of Filyos River (Turkey). Data for annual streamflow and climatic parameters were obtained from streamflow gauging stations on the river and Bartın, Karabük, Zonguldak meteorological observation stations. Time series analysis was performed on 46 years of annual streamflow data and 57 years of annual mean climatic data from three monitoring stations to understand the trends. Pettitt change-point analysis was applied to determine the change time and trend analysis was performed to forecast trends. To reveal the relationship between climatic parameters and streamflow, correlation tests, namely, Spearman’s rho and Kendall’s tau were applied. The results of Pettitt change-point analysis pointed to 2000 as the change year for streamflow. Change years for temperature and precipitation were detected as 1997 and 2000, respectively. Trend analysis results indicated decreasing trends in the streamflow and precipitation, and increasing trend in temperature. These changes were found statistically significant for streamflow ($p < 0.05$) and temperature ($p < 0.01$). Also, a statistically significant ($p < 0.05$) correlation was found between streamflow and precipitation. In conclusion, decreasing precipitation and increasing temperature as a result of climate change initiated a decrease in the river streamflow.

Key words | climate change, Pettitt change-point analysis, streamflow, trend analysis

INTRODUCTION
The Intergovernmental Panel on Climate Change (IPCC) notified that the temperature of ocean and air are increasing (IPCC 2007a). Global mean temperature has increased by 0.74 °C in the last century between the years of 1906 and 2005 and most changes were at about the level of 0.13 °C per decade over the past 50 years (IPCC 2007b). Kale (2017a, 2017b) reported that temperature and evaporation have increasing trends in the future. Following the changes results in variations in the hydrologic cycle such as changed patterns of precipitation, evapotranspiration, and streamflow (Ahmed et al. 2013). Alterations in temperature and precipitation might affect the availability, accessibility, and management of water resources.

Water resources and river streamflow have been affected by climate change due to global warming (Ejder et al. 2016a; Kale et al. 2016a). Effects of climate change and global warming should be considered in water resources management and planning (Fu et al. 2007b). The vulnerability of river streamflow to climate change has been pointed out in numerous studies (Fu & Liu 1999; Fu et al. 2007a; Arnell 2014; Ejder et al. 2016a, 2016b). To estimate the effects of climate change on river hydrology many different methods have been used (Guo et al. 2002; Huo et al. 2008; Liu et al. 2010; Xu et al. 2011; Chen et al. 2012; Islam et al. 2012; Zhang et al. 2012; Bozkurt & Sen 2015). Many techniques have been suggested to understand the possible effects, such as nonparametric regression (Bates et al. 2010), linear and piecewise linear regression (Tomé & Miranda 2004), cumulative sum analysis (Levin 2011), and Mann–Whitney test and Pettitt change-point analysis.
(Tomoezuo et al. 2000; Fealy & Sweeney 2005; Li et al. 2005; Beaulieu et al. 2012; Salarjazi et al. 2012). Also, anthropological activities and hydro-climatic changes may be a reason for a significant change in the time series of streamflow. Villarini et al. (2011) suggested that change-point analysis must be applied on time series of hydrological process before evaluating the trends. Determining the trends in time series of streamflow is a significant tool for detecting variations in hydrological systems (Chang 2007). To estimate the future trends, historical monitoring data will make a significant contribution (Büschel & Montanari 2010).

Many studies have pointed out that streamflow could be affected by temperature and precipitation changes. Fu et al. (2007b) stated that temperature and precipitation had effects on the streamflow in addition to the climatic variability. The effects of climate change on the streamflow of Dongliao river basin (Zhang et al. 2012), Frat and Dicle river basins (Bozkurt & Sen 2013), Kapuas River (Herawati et al. 2015), Huangfuchuan river basin (Zhou et al. 2015), Kocabaş Stream (Ejder et al. 2016a), Sarçay Stream (Ejder et al. 2016b), Karamenderes River (Kale et al. 2016a), and Bakırçay River (Kale et al. 2016b) were investigated and the authors found significantly decreasing trends in the streamflow. However, there is no study on the assessment of possible effects of climate change on Filyos River.

The aim of this study is to estimate possible effects of climate change on the streamflow of Filyos River (Turkey). This paper has documented the potential climate change effects on streamflow by representing the relationships between hydro-climatic factors. Trends and change points in time series of the climatic and streamflow data were also determined. Future trends in the streamflow of Filyos River were forecasted.

**MATERIAL AND METHODS**

**Study area**

Filyos River basin is geographically located in the northern part of Turkey at the southern coast of the Black Sea. Filyos River, the biggest river in Bat Karadeniz Basin, is 228 km in length and has a 13,300 km² total drainage basin (Ünal 2015). Also, its water potential is 1,303.6 km² (Ünal 2015). Its annual average discharge was 100.7 m³s⁻¹ and highest and lowest discharges were recorded as 533 m³s⁻¹ in April 1997 and 6.2 m³s⁻¹ in September 1994, respectively, for the period of 1964–1997 (Şarlak 2014). Filyos River generates the biggest valley of Zonguldak, Turkey (Ünal 2015) and presents the most typical characteristics of meandering (Seker et al. 2005). It arises from Aladag Mountain and runs through Bolu, Çankırı, Kastamonu, Karabük, Zonguldak and flows into the southern coast of the Black Sea. The tributaries of Filyos River are Yenice, Devrek, Soğanlı, and Araç Streams. The river conveys 2.8 billion m³/year water (Kucukali 2008). A total of 70% of the river basin area is covered with forested mountains (Kucukali 2014) and 476 km² area of the river basin consists of non-forestry agricultural and urban areas (Ünal 2015). The climate is wet and humid (winter 7 °C, summer 23 °C) in the basin and the total annual precipitation is approximately 1,000 mm in the coastal parts of the basin whereas it decreases to 500 mm in the inner parts of the basin (Jasim 2014). Avci (1998) reported that total annual precipitation was recorded as 1,232 mm in Zonguldak, 1,071.6 mm in Bartın, and 479.8 mm in Karabük. The annual average precipitation was observed to be 102.67 mm, 89.38 mm, and 39.92 mm for the cities of Zonguldak, Bartın, and Karabük, respectively (Avci 1998).

Climatic datasets for temperature and precipitation for the period of 1960 and 2016 were obtained from Bartın, Karabük, and Zonguldak (Figure 1) meteorological observation stations of the Turkish State Meteorological Service of General Directorate of Meteorology. Hydrological data for Filyos River streamflow between the years of 1964 and 2009 were utilized by kind permission of the General Directorate of State Hydraulic Works (DSİ). Annual average values of streamflow, temperature, and precipitation were computed from the mean monthly records from streamflow gauging station and meteorological observation stations. For the annual average, the total number of observations used in the study is 46 for the streamflow and 57 for both climatic parameters. Total numbers of monthly observations are 552 for the streamflow, 1,810 for temperature, and 1,784 for precipitation.

**Change-point analysis**

Numerous approaches and techniques can be used for determining the change points in a time series.
(Radziejewski et al. 2000; Tomozeiu et al. 2000; Fealy & Sweeney 2005; Li et al. 2005; Beaulieu et al. 2012; Chen & Gupta 2012; Salarijazi et al. 2012). In this study, a non-parametric change-point analysis was applied to determine the occurrence of the unexpected variations which is developed by Pettitt (1979). Pettitt’s change-point analysis has been frequently used to determine the changes in observed time series of hydrologic and climatic data (Tomozeiu et al. 2000; Mu et al. 2007; Gao et al. 2011; Bates et al. 2012; Salarijazi et al. 2012; Ejder et al. 2016a, 2016b; Kale et al. 2016a). A change-point analysis is a distribution-free and rank-based test to detect if any important change is in the time series. Change-point analyses were executed in R statistical software (R Core Team 2017).

The null hypothesis of the change-point analysis is that the variables track the distributions having a similar position parameter and indicates the absence of change point, in contradiction of the alternative hypothesis which indicates the presence of a change point. The non-parametric statistic is given below:

\[ K_T = \max |U_{i,T}|, \text{ where } U_{i,T} = \sum_{i=1}^{T} \sum_{j=i+1}^{T} \text{sgn}(x_i - x_j) \text{ for } t = 2, \ldots , T \]

In this formula, the presence or absence of two examples \(x_1, \ldots, x_i\) and \(x_{i+1}, x_T\) in the same population can be verified by \(U_{i,T}\). Change-point absence is the null hypothesis of the change-point test. The significance probability of \(K_T\) which is the test statistic is estimated for \(p \leq 0.05\) with the formula as follow:

\[ p \geq 2 \exp \left\{ -\frac{6 K_T^2}{T^3 + T^2} \right\} \]

**Trend analysis**

Trend analysis is an extensively used method to understand the tendency of changes in a climatic and hydrologic time
series (Hamed & Ramachandra Rao 1998). In this study, trend analysis was applied to determine the trends and the time series of climatic and hydrologic data. Box–Jenkins technique (Box & Jenkins 1976) and ARIMA model were applied in the trend analysis. Also, autocorrelation analyses were executed to compute the reliability of trend analysis results. Trend analyses were performed in SPSS statistical software version 22 (IBM Corp. Released 2013).

For stationary processes, models of autoregressive (AR), moving average (MA), and autoregressive-moving average (ARMA) are applied. However, for non-stationary processes, autoregressive integrated moving average (ARIMA) model is applied. To determine the best fitted model to the time series with the fewest parameters is the purpose of these models. AR model requires minimizing the sum of squared errors using the smallest number of terms that provide a good fit to data. MA model is utilisable to suggest a good fit to various datasets and alterations on multiple exponential smoothing including models that can switch periodic components and trends in data. ARMA model can be developed by combining AR and MA models and it can be used to model a time series with a slighter number of terms more widespread than both AR and MA models. ARMA models are rich and basically suitable models of stationary and ergodic processes. Mixed models which can be implemented in an extensive range of conditions can be generated through merging the AR and MA models. These well-known mixed models are ARMA and ARIMA models. In ARMA models, the AR and MA models can be merged with only adding them together as a model of order \((p, q)\). Here, \(p\) is AR term and \(q\) is MA term. The ARMA model is expressed below:

\[
X_t = \Phi_1 X_{t-1} + \cdots + \Phi_p X_{t-p} + \varepsilon_t + \theta_1 \varepsilon_{t-1} + \cdots - \theta_q \varepsilon_{t-q}
\]

On the other hand, while ARMA model assumes that the time series is stationary, in fact, trends and periodicity occur in such datasets. Thus, there is a necessity to reduce these effects before carrying out models. Elimination is typically applied by covering in the model a preliminary differencing period until the series is at slightest about stationary that demonstrates no obvious trends or periodicities. The process of differencing is described by the differencing order similar to the AR and MA processes. Supportively, these three components generate a multiple form \((p, d, q)\) which defines the applied model form. Here, the model is explained as an ARIMA model. In ARIMA models, \(p\) identifies the number of AR terms, \(q\) identifies the number of MA terms, and \(d\) identifies the order of differencing. The models are commonly referred to as ARMA \((p, q)\) models if no differencing is done \((d = 0)\). The letter ‘\(I\)’ in ARIMA is the abbreviation of the term ‘integrated’ and specifies that the dataset has been primarily discriminated. Then, the dataset has to be integrated to generate the final estimations and projections when the modeling completes the results. The goal of these models is to identify the best model fitting to the time series and encompassing the least parameters (Box & Jenkins 1976). ARIMA model uses a linear combination to estimate the time series. ARIMA assists to decide on the ‘right model’ to fit the time series. The ARIMA model can be shown as follows:

\[
X_t = c + \Phi_1 X_{t-1} + \cdots + \Phi_p X_{t-p} + \theta_1 \varepsilon_{t-1} + \theta_q \varepsilon_{t-q} + \varepsilon_t
\]

In this formula, \(X_t\) is the variable described in \(t\) time, \(c\) is the constant, \(\Phi\) is coefficient of per \(p\) parameter, \(\theta\) is coefficient of per \(q\) parameter, and \(\varepsilon_t\) are the errors in \(t\) time.

**Mann–Kendall test**

A non-parametric Mann–Kendall (M-K) test (Mann 1945; Kendall 1955) can be applied for identifying the trends in a time series. Mann (1945) first performed this test and then Kendall (1955) designed the distribution of test statistic. The World Meteorological Organization (WMO) mostly recommended the Mann–Kendall test (Mitchell et al. 1966). Furthermore, many scientists have used this test to evaluate the trends in water resources data (Kahya & Kalayci 2004;
Salarijazi et al. 2012; Ejder et al. 2016a, 2016b). Hence, the Mann–Kendall test is an important tool for determining trends. Non-parametric tests were calculated in Minitab statistical software version 17 (MINITAB 2010). The null hypothesis of the Mann–Kendall test is that the values of time series are independent and distributed identically in contrast to the alternative hypothesis that there is a linear or non-linear monotonic trend in the time series. The test statistics can be explained as follows:

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

where the time series \( x_i \) is from \( i = 1, 2, \ldots, n - 1 \), and \( x_k \) from \( k = i + 1, \ldots, n \).

\[ \text{sgn}(\theta) = \begin{cases} +1, & \theta > 0 \\ 0, & \theta = 0 \\ -1, & \theta < 0 \end{cases} \]

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

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

\[ \beta = \text{Median}\left(\frac{x_i - x_j}{i-j}\right), \quad \forall j < i \quad \text{where} \ 1 < j < i < n \]

A positive value of \( \beta \) indicates a rising trend, while a negative value of \( \beta \) indicates a declining trend.

**Spearman’s rho test**

Spearman’s rho (SR) test is a non-parametric test used to measure the strength of a monotonic relationship between two variables (Lehmann 1975; Sneyers 1990). Spearman’s rho test was performed to compare with the Mann–Kendall test. The null hypothesis of the Spearman’s rho test is that data are identically distributed and independent. The alternative hypothesis is that the trend exists in time series. The result will always be between +1 and −1. The test statistics of the Spearman’s rho test are described as:

\[ \rho = 1 - \frac{6 \sum d^2}{n(n^2 - 1)} \]

In this equation, \( d \) is the difference in paired ranks and \( n \) is the number of observations. A positive value of \( \rho \) directs an upward trend while a negative value indicates the downward trend.

**Time series analysis, future forecasting and accuracy controlling**

A time series is an observation collection on a quantitative variable obtained over time. It is a statistical technique that puts into practice time series data to describe the past or to project future events. In time series analysis, the past behavior of a variable is analyzed in order to predict its future behaviors. Analyzing the trends is crucial before generating a time series model.

Time series forecasting relies on the theory that the future can be forecasted by analyzing past historical data. It supposes that factors affecting past and present will remain affecting in the future. In this study, three possible accuracy measures (mean absolute deviation, MAD; mean squared deviation, MSD; mean absolute percentage error, MAPE) are used to calculate the accuracy of forecasting. These measures are dependent on the deviation or error between the actual and forecasted values.

**Mean absolute deviation (MAD)**

Mean absolute deviation states accuracy in the same units as the data and aids in theorizing the amount of error. The equation is given below:

\[ MAD = \frac{\sum_{i=1}^{n} |y_i - \hat{y}_i|}{n} \]

In this formula \( y_i \) is the actual value, \( \hat{y}_i \) is the forecast value, and \( n \) is the observation number.
Mean squared deviation (MSD)

Mean squared deviation is a widely used accuracy measure of forecasted values of time series. Outliers have a greater impact on MSD than on MAD. The equation is as follows:

$$MSD = \frac{\sum_{i=1}^{n} |y_i - \hat{y}_i|^2}{n}$$

In this equation, $y_i$ is the actual value, $\hat{y}_i$ is the forecast value, and $n$ is forecast number.

Mean absolute percentage error (MAPE)

Accuracy is described as a percentage of the error in MAPE. Understanding the statistic might be easier than other statistics due to the fact that it is a percentage. The formula of MAPE is expressed as:

$$MAPE = \frac{\sum_{t=1}^{n} \left| \frac{y_t - \hat{y}_t}{y_t} \right| \times 100, \quad (y_t \neq 0)}{n}$$

In this equation, $y_t$ is the actual value, $\hat{y}_t$ is the forecast value, and $n$ is observation number.

RESULTS AND DISCUSSION

The basic statistics of the streamflow, temperature, and precipitation in the study, including mean, maximum, and minimum values, range, standard deviation, coefficient of variation (CV), coefficient of skewness, and coefficient of kurtosis are listed in Table 1. CV is the most discriminating factor among these factors. If the CV value is less than 0.1, the parameter displays low variability. It displays high variability when the CV value is greater than 0.9 (Durdu 2010). The results of basic statistics show that the CV values for streamflow and precipitation are greater than 0.1 (CV = 0.30, CV = 0.19, respectively) and for temperature is less than 0.1 (CV = 0.05). However, all parameters are less than 0.9. Consequently, it can be concluded that temperature data have low variability and streamflow and precipitation data present moderate variability. A negative kurtosis value mainly gives a flat distribution where many data are in the tails and not enough in the center. On the other hand, a positive kurtosis value means that there are few data points in the tails. The kurtosis value of zero presents a perfectly symmetrical bell curve.

The results of Pettitt change-point analysis indicated that the change years for precipitation and temperature were 2000 and 1997, respectively (Table 2). Trend analysis results demonstrated that an increasing trend has been forecasted in temperature and a decreasing trend has been anticipated in precipitation (Figure 2).

For the river streamflow, Pettitt change-point analysis results showed that the change year was 2000 for Filyos River (Table 2). Trend analysis results showed that streamflow has a downward trend (Figure 3). According to the results of trend analyses, future predictions for streamflow, temperature, and precipitation are given in Table 3. These results were forecasted by time series analysis using ARIMA (0, 1, 1) model. Box & Jenkins (1976) suggested the usage of the autocorrelation function (ACF) and the partial autocorrelation function (PACF) as the fundamental analyses for determining the order of ARIMA model. ARIMA (0, 1, 1) model was selected according to the outputs of analyses of ACF and PACF. Moreover, the best fit model is the model through random residuals at a certain significance level. Therefore, the significance levels of ARIMA models were compared with each other and Ljung-Box test statistic was used to check the randomness.

### Table 1 | Basic statistics of streamflow and climate data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>N</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>Maximum value</th>
<th>Minimum value</th>
<th>Range</th>
<th>Coefficient of variation</th>
<th>Coefficient of skewness</th>
<th>Coefficient of kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Streamflow (m³ s⁻¹)</td>
<td>46</td>
<td>97.72</td>
<td>28.88</td>
<td>195.93</td>
<td>33.07</td>
<td>162.85</td>
<td>0.30</td>
<td>−0.19</td>
<td>2.10</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>57</td>
<td>13.29</td>
<td>0.69</td>
<td>15.05</td>
<td>11.98</td>
<td>3.08</td>
<td>0.05</td>
<td>0.36</td>
<td>−0.22</td>
</tr>
<tr>
<td>Precipitation (mm)</td>
<td>57</td>
<td>81.88</td>
<td>15.65</td>
<td>119.76</td>
<td>54.18</td>
<td>65.58</td>
<td>0.19</td>
<td>0.78</td>
<td>0.12</td>
</tr>
</tbody>
</table>
Finally, R-squared values were taken into account to choose the best model. R-squared values close to zero indicate a good fit. Consequently, ARIMA (0, 1, 1) model was selected to forecast the future trends of parameters (Table 4).

Time series models offer higher forecast precision in different conditions. To measure the accuracy of forecasting, we used MAD, MSD, and MAPE. MAD is the mean of the summation of total errors. In the literature, if MAPE is less than 10%, it reflects that the forecast is extremely accurate (Lewis 1982). MAPE prevents the interpreting problem of the accuracy measure corresponding to the greatness of the actual and the forecast values. MAPE values for temperature are found less than 10%. Therefore, it can be concluded that the forecasting for temperature is highly accurate in contrast to precipitation and streamflow. However, these forecasts are based merely on time series. The relationship between streamflow and climatic parameters should also be considered for further studies to predict the future values.

The Mann–Kendall test determines the presence or absence of a monotonic trend in a time series while Spearman’s rho test measures the strength and direction of a relationship between two variables. The Mann–Kendall test has been widely used to evaluate the significance of trends in time series. Table 2 presents the test statistics of all parameters for before and after change points. For the whole dataset, statistically significant correlation was found between streamflow and precipitation (\(p = 0.016\) and \(p = 0.024\) from Spearman’s rho test and Mann–Kendall test, respectively). The correlation between temperature and streamflow was found to be statistically insignificant (\(p = 0.074\) and \(p = 0.116\) from SR and M-K tests, respectively).

The decreasing trend of precipitation and increasing trend of the temperature were found statistically insignificant (\(p = 0.100\) and \(p = 0.147\) from SR test, \(p = 0.117\) and \(p = 0.120\) from M-K test for precipitation and temperature, respectively). On the other hand, declining trend of the streamflow was found statistically significant (\(p = 0.017\) and \(p = 0.015\) from M-K and SR tests, respectively). Test statistics of both non-parametric tests are presented and compared in Tables 5 and 6.

The mean annual streamflow before the change point was recorded as 103.06 m³s⁻¹ while it was observed to be 78.494 m³s⁻¹ after the change point. Maximum monthly average streamflow was documented as 587 m³s⁻¹ in December while the minimum occurred in September with 6.2 m³s⁻¹. Mean annual temperature was observed as 13.08 °C before the change point and 13.71 °C after the change point. Maximum monthly mean temperature was recorded as 27.7 °C in August while the minimum of −1.4 °C was observed in January. For precipitation, annual average was recorded as 84.59 mm before the change point and 74.51 mm after the change point. Maximum monthly mean precipitation was noted to be 13.08 mm in November. The variation of mean monthly streamflow of the river corresponds to mean monthly precipitation and temperature as shown in Figure 4.

Understanding the impacts of the climate change and considering the consequences of different climate change scenarios on the streamflow are important (Kale et al. 2016). Durdu (2010) pointed out that climate change and variations in precipitation trends could have impacts on the natural water resources availability. Therefore, the exploration of variations in the river streamflow is crucial.
to management and to maintain the sustainability of water resources.

Chen & Xu (2005) documented that global warming could be a reason for rising temperatures. Most climate models forecast an increase in temperature and a decrease in precipitation at the end of the 21st century (García-Ruiz et al. 2011). In this study, an increasing trend in temperature and a decreasing trend in precipitation are expected in the future. Variations in the precipitation may have a direct effect on the river streamflow (Kale et al. 2018). Moreover, some authors have documented that climate change could lead to decreasing
trends in the river streamflow (Kahya & Kalaycı 2004; Durdu 2010; Bahadir 2011; Koçman & Sütgibi 2012). This paper predicts a decreasing trend in the streamflow of Filyos River. Similarly, many authors have reported downward trends in the streamflow of rivers. Alcamo et al. (2007) documented that the streamflow of rivers has a tendency to decrease in several parts of southern Europe. Herawati et al. (2015) indicated a declining trend in streamflow of rivers in Indonesia. Zhou et al. (2015) indicated a permanent decrease in the streamflow of Huangfuchuan River. Li et al. (2016) projected a decrease in the streamflow of Songhua River Basin related to decreasing precipitation and increasing temperature. Pumo et al. (2016) reported a significant decrease in the streamflow of rivers in Italy. Ozkul (2009) and Ozkul et al. (2008) called attention to downward trends in the streamflow of Gediz River and Büyük Menderes River. Türkeş & Acar Deniz (2011) stated decreasing trends in the streamflow of the rivers in the southern part of Marmara. Ejder et al. (2016a) reported a decreasing trend in the streamflow of Kocabaş Stream. Ejder et al. (2016b) indicated a downward trend in the streamflow of Sarıçay Stream. Kale et al. (2016a) found a decreasing trend in Karamenderes River streamflow. Kale et al. (2016b) documented that the streamflow of Bakiçay River tended to decrease. Kale et al. (2018) reported decreasing trends in the streamflows of Büyük Menderes, Gediz, and Tuzla Rivers.

Kucukali (2008) pointed out that maximum streamflow could occur at maximum level due to the snowmelt and it could be observed at minimum level because of the precipitation scarcity. In the river basin, snow melting occurs between the period of February and April (Kucukali 2008). The river streamflow continues to increase despite the increase in temperature and the decrease in precipitation. It can be explained by the snow melting. However, maximum monthly mean streamflow was recorded in December and minimum was observed in September for
this study. Also, maximum monthly average precipitation amount and minimum monthly mean temperature were noted in November and August, respectively. Therefore, it can be concluded that rising temperature and decreasing precipitation could have more effects than snow melting on the streamflow of the river.

There is a considerable fluctuation in the streamflow between dry and wet seasons. Mean streamflow was observed as 222.4 m$^3$s$^{-1}$ in April while it was 22.6 m$^3$s$^{-1}$ in September. This notable difference could lead to deposition and suspension of sediment. Similarly, Akyüz et al. (2014) indicated that resuspension of sediment in wet seasons and sediment accumulation in dry seasons were the main results of variations in the streamflow between wet and dry seasons. The river regime has become disordered due to the accumulated sediment fields and the risk of flooding increases. On the other hand, a flood occurred on 21 May 1998 and lasted 48 hours in Filyos River. The peak flow of this flood could not be measured (Kutoglu 2006). Akyüz et al. (2014) noted that damage caused by the

<table>
<thead>
<tr>
<th>Table 4</th>
<th>Parameters of ARIMA models</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>Parameter</td>
</tr>
<tr>
<td>ARIMA (0, 1, 1)</td>
<td>q</td>
</tr>
<tr>
<td>ARIMA (1, 1, 1)</td>
<td>p</td>
</tr>
<tr>
<td></td>
<td>q</td>
</tr>
<tr>
<td>ARIMA (1, 1, 0)</td>
<td>p</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 5</th>
<th>Test statistics and comparison of Mann-Kendall test and Spearman's rho test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method</td>
<td>Parameter</td>
</tr>
<tr>
<td>Mann–Kendall test</td>
<td>Streamflow</td>
</tr>
<tr>
<td></td>
<td>p</td>
</tr>
<tr>
<td></td>
<td>Temperature</td>
</tr>
<tr>
<td></td>
<td>p</td>
</tr>
<tr>
<td></td>
<td>Precipitation</td>
</tr>
<tr>
<td>Spearman's rho test</td>
<td>Streamflow</td>
</tr>
<tr>
<td></td>
<td>p</td>
</tr>
<tr>
<td></td>
<td>Temperature</td>
</tr>
<tr>
<td></td>
<td>p</td>
</tr>
<tr>
<td></td>
<td>Precipitation</td>
</tr>
</tbody>
</table>

Note: CC indicates correlation coefficient; p indicates the significance level of the correlation.
*Correlation is significant at the 0.05 level.

<table>
<thead>
<tr>
<th>Table 6</th>
<th>Comparison of non-parametric tests values and trend status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
<td>Kendall's tau</td>
</tr>
<tr>
<td>Streamflow</td>
<td>-0.244</td>
</tr>
<tr>
<td>Temperature</td>
<td>0.142</td>
</tr>
<tr>
<td>Precipitation</td>
<td>-0.143</td>
</tr>
</tbody>
</table>

▼ indicates statistically significant decreasing trends.
△ indicates statistically insignificant downward trends.
↑ indicates statistically insignificant upward trends.
flood was around 120 million USD. Subsequently, scientific researches were conducted and an early warning flood system (Turkish Emergency Flood and Earthquake Recovery; TEFER) was established in the river basin. It is possible to be faced with such disasters if the streamflow cannot be controlled and steady flow cannot be ensured in the future.

Forthcoming scenarios for water resources expected changes in river regime are a reduction in the average streamflow, variations in coastal areas, and modifications in reservoir management and contributions (García-Ruiz et al. 2014). Forecasting future impacts of climate change on the river streamflow is difficult due to the complexity and inconsistency of climate systems. There are some different models for assessing the climate change impacts on the hydrological processes of rivers, including general circulation models (GCM) (Guo et al. 2002; Xu et al. 2011; Chen et al. 2012; Bozkurt & Sen 2013), regional circulation models (RCM) (Guo et al. 2002), precipitation runoff modeling system (PRMS) (Islam et al. 2012), soil and water assessment tool (SWAT) (Xu et al. 2011; Zhang et al. 2012; Li et al. 2016). These models could be insufficient, attributable to lack of data or unreliability of the data. Globally projected simulations may possibly not be usable regionally. Limitations of this investigation might be inconsistency of climate systems or data incompleteness. Long-term and non-discrete data have been used to eliminate these limitations in this study. Therefore, it is important to choose the most appropriate hydrological model for predicting the possible impacts of the climate change on the river streamflow since fluctuations in the streamflow vary between the locations depending on the climatic conditions (Chien et al. 2013).

CONCLUSION

This paper provides first knowledge on the assessment of possible effects of climate change on Filyos River. A decrease in streamflow of Filyos River is predicted, attributed to decrease in precipitation and increase in temperature. A statistically significant correlation was found between the streamflow and precipitation. Possible impacts of climate change could be a reason for declining and reduction in the amounts of available water resources. Therefore, planning and effective management of water resources is crucial to ensure the sustainability of water resources. Current water management policy for Filyos River should be reviewed and the most applicable assessment models should be applied to maintain the amounts of available water resources. It is recommended that dam building on the river may be effective and beneficial to prevent flash floods and to ensure the sustainable use of water resources. It is of crucial importance to moderate the negative effects on streamflow caused by many reasons, mainly climate change.

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