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Restricted effects of climate change on annual streamflow of Sarıçay stream (Çanakkale, Turkey).

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ABSTRACT

The global warming and the associated climate change lead to significant problems related to sustainability of natural resources. The observations and research on this issue have shown that most of the water resources have been affected by this phenomenon. These effects of global warming on water resources can be listed as decreased amount of water and droughts in mid-latitude belt. In the current study the changes in the flows of Sarıçay stream in Çanakkale and the time series of the climate parameters related to the region were determined and trends of these variations were estimated. A 34-years data set regarding the river flows between 1978 and 2011 as well as some annual climate parameters such as temperature, evaporation and precipitation have been collected by three meteorological observation stations (Bozcaada, Gökçeada, Çanakkale) for 43 years were used. Pettitt change-point analysis was used to determine the change points for streamflow and climatic parameters. Box-Jenkins method and the ARIMA model were used for trend analyses. Results showed that there was a decrease in precipitation and streamflow on the contrary an increase in evaporation and temperature. However, these changes were statistically insignificant ($P > 0.05$). In conclusion, climate change effects on river streamflow could be unstable and many factors such as latitudinal location, anthropogenic effects, agricultural activities, population density and residential areas could affect the streamflow.

Introduction

Recently, it has been observed that global warming causes serious problems throughout the world. The studies have revealed that there has been an increase in global surface temperature on average by 0.7°C since the beginning of the century and an increase of 3°C is expected in the following century. In addition, the potential impact of climate change caused by global warming on basic climate parameters such as increase in average temperature, change in precipitation patterns, drought, flash floods and rise in sea level has been foreseen (IPCC 2007).

Climate is an important factor affecting river flows. River currents may vary depending on the climate characteristics in the region where they are located. The region's vegetation, soil structure, geological and geomorphological features also have an effect on river currents (Atalay 1986). However temperature and precipitation especially constitute the basic entries of hydrological system (Isaak et al. 2012). The fact that the increase in global surface temperature alters the thermal regimes in aquatic ecosystems, it is known that rainfall has also a significant impact on available water potential. Many factors such as geographical location, topography, air masses and frontal systems may affect the amount and distribution of rainfall (Çiçek and Ataol 2009).

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Although many scenarios concerning climatic and hydrological changes resulting from global warming are generated, there were not enough studies pertaining to changes in flows of river systems (Kojiri et al. 2008). Therefore, the aim of this study is to determine the interaction between streamflow of Sarıçay stream and climatic changes in the region and to make predictions by identifying the flow changes having occurred in the years.

Material and methods

Study Area

Sarıçay Stream arises from Ida Mountains and runs through Çanakkale city centre. The river flows into Çanakkale Strait, the north-western Turkey. Sarıçay stream is 40 km in length (Kaya et al. 2014a) and its discharge is changing between 15 – 1300 $m^3 s^{-1}$ (Kaya et al. 2014b). The streamflow and water carrying capacity vary by season (Akbulut et al. 2010).

Temperature, evaporation and precipitation data collected from 3 meteorological observation stations belong to the Turkish State Meteorological Service of General Directorate of Meteorology were utilized as elementary climatic parameters belonging to 1970 - 2012 years. These meteorological observation stations are Bozcaada, Gökçeada and Çanakkale (Figure 1) located in the coasts of Çanakkale province. Annual average streamflow data belonging to Sarıçay Stream was used with the approval of the General Directorate of State Hydraulic Works (DSİ).

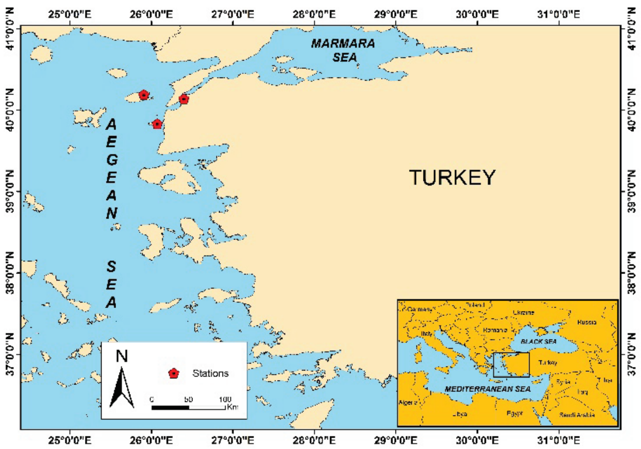

Figure 1. Meteorological observation stations.

Change Point Analysis

Pettitt's change-point analysis was used to determine the change time of the climatic parameters and river streamflow (Pettitt 1979). This statistical test which was modified from the Mann-Whitney statistic determines the change by calculating how many times the first example's member exceeds a member of the second example.

Trend Analysis

To determine the tendency of changes in a hydrological and climatic time series, trend analysis was used. In addition, Box-Jenkins technique (Box and Jenkins 1976) was applied in the trend analysis to determine the tendency and the time series of temperature, evaporation, precipitation and the flow series of Sarıçay Stream. Trend analyses and correlation were conducted to analysis of relation levels and future trends. The ARIMA (1, 0, 1) model was used in trend analyses. Autocorrelation analyses were performed to calculate reliability of the results. It was targeted to present quantitative forecasting by foreseeing the statistical data analysis in the streamflow and the climatic data. It is undertaken to forecast future projections by foreseeing a 5-years range implemented to the time-series.

Mann-Kendall Test

A non-parametric Mann-Kendall test was used to investigate the potential trends in the temperature, evaporation, precipitation and streamflow of Sarıçay Stream with some extreme values in this study (Kendall 1955; Mann 1945). *Kendall's tau* and *Spearman's rho* tests were performed to determine the correlations between streamflow of the river and climatic parameters.

Results

The Pettitt change-point analysis results showed that the change point for evaporation, temperature and precipitation was 1993, 1997 and 1993, respectively (

Table 1). As a result of the trend analyses, it was found that the levels of temperature and evaporation have a tendency to increase and that the level of precipitation tends to decrease (Figure 2). Trend analyses showed that the evaporation and temperature levels will increase annually 1.44425 mm and mm and 0.02875°C, respectively, and they

Table 1. Results of Pettitt change-point analysis, *Kendall's tau* and *Spearman's rho* tests for climate parameters.

Climatic Parameters	Pettitt Change Year	Mann-Kendall				Spearman			
		First Stage		Second Stage		First Stage		Second Stage	
		tau	*p*	*tau*	*p*	*rho*	*p*	*rho*	*p*
Sarıçay	1999	-0.019	0.904	0.026	0.903	-0.051	0.827	-0.027	0.929
Temperature	1997	-0.071	0.602	0.300	0.105	-0.107	0.596	0.113	0.412
Evaporation	1993	0.286	0.070	0.232	0.153	0.406	0.067	0.307	0.188
Precipitation	1993	-0.502	0.001	-0.074	0.650	-0.705	0.0002	-0.108	0.650

a *First Stage* is from 1978 to the change year and *Second Stage* is from the change year to 2011 for annual streamflow of Sarıçay Stream. For climatic parameters, *First Stage* is from 1970 to the change year and *Second Stage* is from the change year to 2012. *tau* and *rho* are test statistics. *p* is significance level.

Table 2. Trend analysis forecasting for annual streamflow of Sarıçay Stream and annual temperature, evaporation, precipitation.

Years	Sarıçay Stream (m^3 s^{-1})	Temperature(°C)	Evaporation (mm)	Precipitation (mm)
2016	0.809473	16.0341	205.128	48.3797
2017	0.802670	16.0629	206.572	48.2797
2018	0.795867	16.0916	208.016	48.1797
2019	0.789064	16.1204	209.461	48.0798
2020	0.782261	16.1491	210.905	47.9798

will reach 210.905 mm and 16.1491°C by 2020. Precipitation is expected to reach 47.9798 mm in 2020 by decreasing 0.099975 mm annually (Table 2).

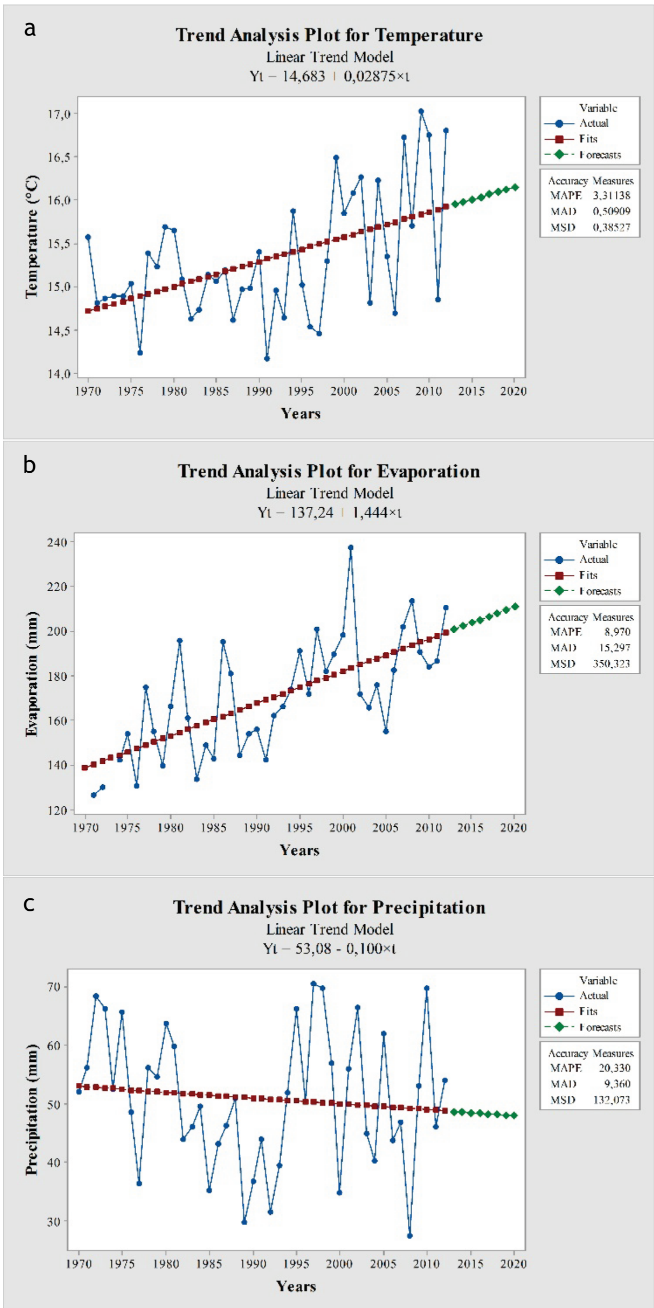

Figure 2. Trend analysis results for climatic parameters (*a: Temperature; b: Evaporation; c: Precipitation*).

The change year for Sarıçay was determined as 1999 according to the Pettitt change point analysis carried out to determine the significant change time in streamflow. As a result of the trend analyses, it was determined that streamflow of the river tend to decrease (Figure 3) and the amount of this decrease is predicted to be 0.006803 m^3 s^{-1}. The streamflow of the river is predicted to reach 0.782261 m^3 s^{-1} in 2020 by the 5-years projection of the trend analysis (Table 2).

As a result of the non-parametric tests, the correlation between the river streamflow after the change point years and the temperature, evaporation, precipitation was found statistically insignificant ($P > 0.05$). However, before the change year, the correlation between the river streamflow and climatic parameters was found statistically significant ($P < 0.05$). This variation indicates that annual streamflow of Sarıçay Stream decreased significantly until the change year. Then, the decreasing in the streamflow decelerated.

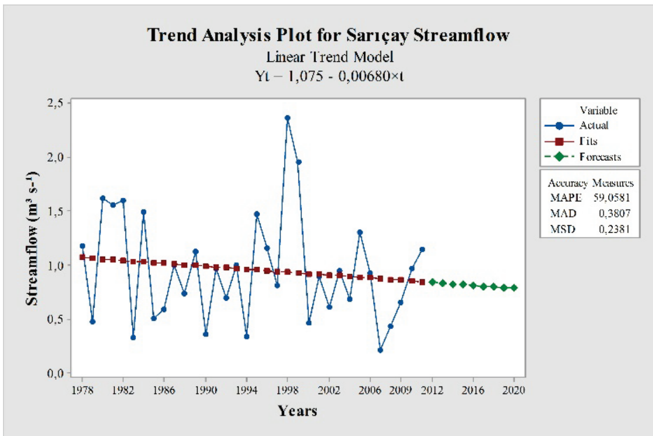

Figure 3. Trend analysis results for annual streamflow of Sarıçay Stream.

Discussion

It is supposed that global surface temperature will be influenced by climate change and increase by 1.5 – 5.8°C before 2100 (Harrison et al. 2003). According to this scenario, Turkey is one of the countries at risk of global warming and climate change (Hisar et al. 2015). Increasing drought or excessive precipitation in some places is expected as a result of climate change. Increased evaporation and temperature in addition to decreased precipitation causes make more violent the hydrological cycle and leads to raining seasons to be even wetter and dry seasons to be even drier (IPCC 2001). Ünal and Ünol (2011) concluded from the simulated models that minimum and maximum temperatures will rise at least by 0.5 – 1.0°C and 0.5 – 1.5°C between 2010 and 2039, respectively. Türkeş et al. (2009) reported that rainfall amount and intensity tend to decrease in Turkey. Besides, it has been expected that increase in water temperature and rainfall fluctuations will change the amount of water and flow rates. Durdu (2010) forewarned that natural water resources availability in Turkey will decrease due to the climate change and changes in precipitation rates leading to a water stress.

It is projected that there were increases in the temperature and evaporation and a decrease in precipitation according to the trend analyses. Chen and Xu (2005) pointed out that global warming may lead to an increase in the evaporation and temperature. Many authors reported that the temperature and evaporation levels are increased statistically significantly in Europe (Alcamo et al. 2007), Middle East (Zhang et al. 2005) and Turkey (Durdu 2010; Sensoy et al. 2008; Sütgibi 2015). Durdu (2010) reported that there was an insignificant decrease trend in Büyük Menderes river basin. In climate models, the scientists have an agreement on a global warming and there lasts much uncertainty regarding the changes in precipitation. Although some scientists anticipate that winters will be rainier in global circulation scenarios, the others expect that the fluctuations in precipitation will be significant in summers and drier winters (Dixon et al. 2009).

It was determined that there was a decreasing trend in the streamflow of Sarıçay Stream. Many authors reported downward trends in the streamflow of the rivers. Zhou et al. (2015) notified that there was a continuous decrease in the streamflow of Huangfuchuan river in China. Herawati et al. (2015) determined a decreasing trend in the annual streamflow in Indonesia and the authors concluded that the hydrological characteristics of the river affected by the climate change. Pumo et al. (2016) claimed that the precipitation rates and the streamflow showed a significant tendency of decrease in non-perennial minor rivers of Italy. Ozkul et al. (2008) and Ozkul (2009) reported that there were decreasing trends in the streamflow of Büyük Menderes and Gediz rivers. Türkeş and Acar Deniz (2011) found a decreasing trend in the streamflow and precipitation in the southern Marmara.

There are several studies on global warming effects on the streamflow in western Turkey. Several authors reported that the river streamflow have decreasing trends due to the climate change effects such as decreasing precipitation and increasing temperature (Bahadir 2011; Durdu 2010; Kahya and Kalaycı 2004; Koçman and Sütgibi 2012). In this study, a decreasing trend was determined in the streamflow of Sarıçay Stream similar to the precipitation rates, on the contrary of the trends in temperature and evaporation. However, the relationship between the streamflow and the climatic parameters is statistically insignificant ($P > 0.05$). Bates et al. (2008) declared that the trends in the streamflow were not associated to the fluctuations in the precipitation all the time. Otherwise, several authors stated that agricultural activities (Durdu 2010; Dügel and Kazanci 2004; Kaçan et al. 2007; Yercan et al. 2004), hydraulic structures (Ozkul et al. 2008) and anthropogenic activities (Gao et al. 2011; Jackson et al. 2011; Zhou et al. 2015) had effects on the river streamflow similar to the climate change effects.

In conclusion, it was found that there were decreasing trends in precipitation and Sarıçay streamflow, and that there were increasing trends in evaporation and temperature in north-western Turkey. It is envisaged that climate change may have different effects at regional level, could cause water shortages and may increase the existing problems. Changes in water resources may also affect economic development. Conflicts between masses are also predicted to occur due to current anthropogenic activities and those gradually increase. Water resources have to be managed in a more efficient manner on account of the reduction in water resources, the increasing need for drinking water and agricultural irrigation. Therefore, the existing water management plans should be revised and suitable management plans should be established. In this context, planning decisions for water resources must be made not only in consideration of water demand, but also issues such as control of the existing water use, supply and demand balance, water storage areas, water sustainability, expansion of water sharing policy and water monitoring network.

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