

# MARINE SCIENCE AND TECHNOLOGY BULLETIN

## Climate Change Impacts On Streamflow of Karamenderes River (Çanakkale, Turkey).

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### ABSTRACT

The main objective of this study was to estimate the potential impacts of climate change due to the global warming on streamflow of Karamenderes River (Çanakkale, Turkey). A 36-years dataset belongs to the streamflow of Karamenderes River and a 43-years dataset belongs to the climatic parameters (temperature, precipitation, and evaporation) obtained from Çanakkale, Bozcaada, Gökçeada meteorological stations in Çanakkale. Time series analysis was applied to the streamflow and climatic parameters. Pettitt change point analysis was performed to detect the change time and trend analysis was applied for estimating the trends. Kendall's tau and Spearman's rho correlation tests were applied to find out the relationship between streamflow and the climatic parameters. Pettitt change point analysis results indicated that the change year for streamflow was 1982. Trend analysis results showed that there were decreasing trends in the streamflow and precipitation, and increasing trends in temperature and evaporation. Correlation tests results pointed out that these changes were statistically insignificant. Increasing temperature and decreasing rainfall due to the climate change caused a decrease in the streamflow of the river. In conclusion, the climate change impacts on streamflow could be variable. Also, anthropogenic effects and agricultural activities may affect the responses of the rivers to the global warming and climate change impacts. It is suggested that dam building on the rivers might be beneficial to provide more water for irrigation or other purposes in sustainable way.

### Introduction

Climate change have an important impact on agriculture (Beaulieu et al., 2012), river streamflow (Ejder et al., 2016a) and water resources. Management and planning of water resources require to include in the scope the impacts of climate change and global warming (Fu et al., 2007b). Several studies have been published to highlight the susceptibility of streamflow to climate changes worldwide (Arnell, 2014; Ejder et al., 2016a, b; Fu et al., 2007a; Fu and Liu, 1991). Hydro climatic changes and anthropological

activities may lead to a variation in the time series of a river streamflow. Detecting the trends in streamflow is an essential tool for determining alterations in hydrological systems (Chang, 2007). Using historical surveillance datasets may help to comprehend what will happen in the future (Blöschl and Montanari, 2010).

Several different methodologies can be used to expect climate change effects on river hydrology (Bozkurt and Sen, 2013; Chen et al., 2012; Guo et al., 2002; Huo et al., 2008; Islam et al., 2012; Liu et al., 2010; Xu et al., 2011; Zhang et al., 2012). Numerous techniques have been recommended to overcome the problem comprising nonparametric regression (Bates et al., 2010), t-tests (Marengo and Camargo, 2008),

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cumulative sum analysis (Levin, 2011), linear and piecewise linear regression (Tomé and Miranda, 2004) and Mann-Whitney test and Pettitt change point analysis (Beaulieu et al., 2012; Fealy and Sweeney, 2005; Li et al., 2005; Salarijazi et al., 2012; Tomozeiu et al., 2000).

Many studies put forward that hydrological time series of streamflow show a significant change point or trend by the reason of the impacts of climate change or anthropological activities on water resources. Walling and Fang (2003) pointed out that approximately 22% of the rivers worldwide displayed significant decreasing trend and approximately 9% displayed significant increasing trend. Several authors reported that anthropological activities might play an important role in decrease of streamflow (Gao et al., 2011; Jackson et al., 2011; Salarijazi et al., 2012; Zhou et al., 2015). Yang and Saito (2003) specified that human activities such as water consumption, flow diversion and dam building were causes of the decreasing trends in the annual streamflow. Villarini et al. (2011) recommended that change point analysis must be applied on hydrological time series before assessing trends.

Fu et al. (2007b) indicated that streamflow was responsive to temperature and precipitation besides the climate variability. Many studies have documented that changes in temperature and precipitation might affect river streamflow. Zhang et al. (2012) studied climate change effects on the streamflow of Dongliao river basin and indicated that the streamflow showed a significant decreasing trend associated with precipitation. Bozkurt and Sen (2013) studied climate change effects on the streamflow of Fırat and Dicle river basins and found a significantly decreasing trends. Herawati et al. (2015) investigated climate change effects on the streamflow of Kapuas River and claimed that streamflow showed a decreasing trend. Zhou et al. (2015) studied impacts of the anthropological activities and climate change on the streamflow of Huangfuchuan river basin and stated that streamflow showed a decreasing trend. Pumo et al. (2016) investigated climate change effects on streamflow and stated that streamflow showed a decreasing trend associated with precipitation. Ejder et al. (2016a) studied the effects of climate change on Kocabaş streamflow and pointed out that streamflow showed a decreasing trend. Ejder et al. (2016b) investigated the effects of climate change on Sarıçay streamflow and reported that streamflow showed a decreasing trend.

The main purpose of this study is to investigate potential impacts of climate change on streamflow of Karamenderes River (Çanakkale, Turkey). This study have documented the impacts of climate change on streamflow by indicating the interactions between hydro climatic factors. Change points or trends in streamflow and climatic data were also explored. Change points were determined and the tendency of trends was predicted.

## Material and methods

### Study Area

Karamenderes River is 109 km in length and maximum flow rate of the river is  $1530 \text{ m}^3 \text{ s}^{-1}$  (Anonymous, 2014).

The ancient name of the river is Scamender. The river arises from Ağı and Ida Mountains and run through ancient Troy city and flows into Çanakkale Strait. Its annual water potential is about  $460 \text{ hm}^3$  (Ağırğöl Kayacan, 2008). There are two reservoirs constructed on the river which are Pınarbaşı and Bayramiç. These reservoirs were built to supply water for irrigation to people. Water pollution sources of the Karamenderes River were reported as domestic solid waste, domestic wastewater, industrial wastewater, industrial solid waste, agricultural waste, mine dumps and waste from livestock raising by Anonymous (2014). The river has the only permanent current in the basin (Ağırğöl Kayacan, 2008).



Figure 1. The locations of meteorological observation stations and Karamenderes River.

Climatic dataset for temperature, precipitation and evaporation between the years of 1970 and 2012 were obtained from Çanakkale, Gökçeada and Bozcaada (Figure 1) meteorological observation stations which belong to Turkish State Meteorological Service of General Directorate of Meteorology. Hydrological data for Karamenderes River streamflow were utilized by kind permission of the General Directorate of State Hydraulic Works (DSİ).

### Change Point Analysis

Several approaches can be applied to detect the change points in a time series (Beaulieu et al., 2012; Chen and Gupta, 2012; Fealy and Sweeney, 2005; Li et al., 2005; Radziejewski et al., 2000; Salarijazi et al., 2012; Tomozeiu et al., 2000). In this study, we used non-parametric change-point analysis to detect existence of the abrupt change developed by Pettitt (1979). This statistical analysis is a rank based and distribution-free test to determine a significant change in a time series. Pettitt change point analysis has been commonly applied to determine the changes in observed hydrological and climatic time series (Bates et al., 2012; Ejder et al., 2016a, b; Gao et al., 2011; Mu et al., 2007; Salarijazi et al., 2012; Tomozeiu et al., 2000).

### Trend Analysis

Trend analysis was used to determine the tendency of variations in climatic and hydrological time series. Box-Jenkins technique (Box and Jenkins, 1976) and ARIMA

model (1, 0, 1) was applied in trend analyses. To calculate reliability of the results of trend analyses autocorrelation analyses were implemented.

**Mann-Kendall Test**

A non-parametric Mann-Kendall test (Mann, 1945; Kendall, 1955) can be used to detect the trend in a time series. Mann (1945) initially used this test and then Kendall (1955) formed the test statistic distribution. Mann-Kendall test has been suggested extensively by the World Meteorological Organization (WMO) (Mitchell et al., 1966). Moreover, numerous authors used this test to assess the trend of water resources data (Ejder et al., 2016a, b; Kahya and Kalaycı, 2004; Salarijazi et al., 2012). Consequently, this test has been found to be an important tool to determine the trend.

**Results**

Pettitt change point analysis results indicated that the change point for temperature, evaporation and precipitation was 1997, 1993 and 1993, respectively (Table 1). Trend analysis results pointed out that temperature and evaporation have an upward trend and that precipitation has a downward trend (Figure 2).

In accordance to the trend analyses temperature and evaporation are expected to reach 16.1491 °C and 210.905 mm, respectively, while precipitation is projected to reach 47.9798 mm in 2020 (Table 2).

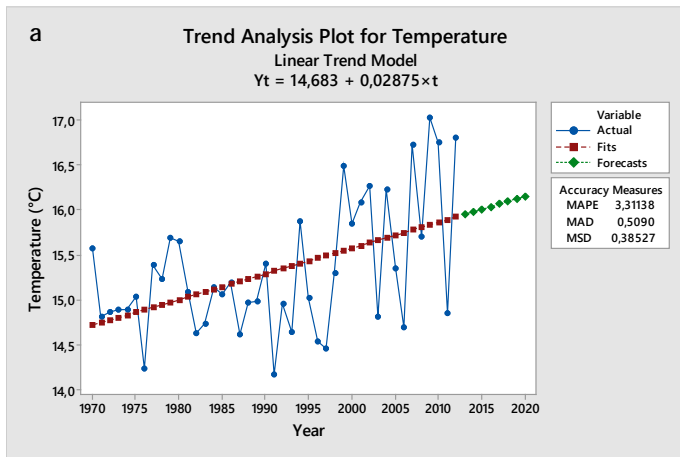
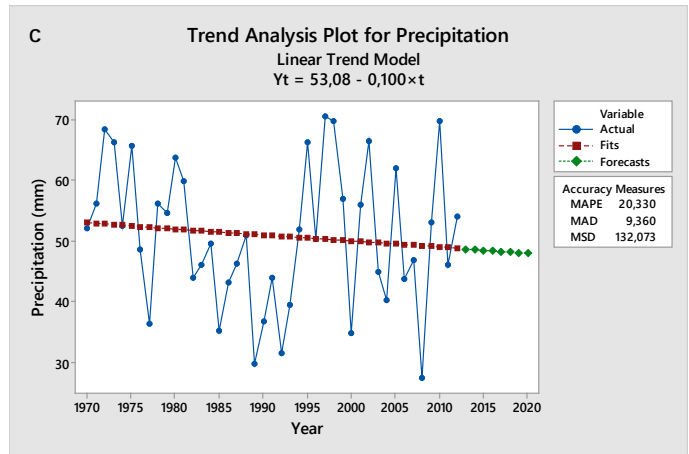
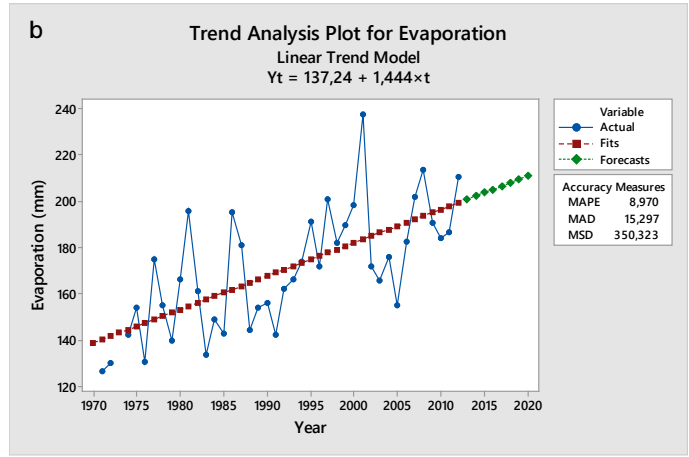


Figure 2. The results of trend analyses for climatic parameters (a: Temperature; b: Evaporation; c: Precipitation).

The change year for Karamenderes river streamflow was detected as 1982 in accordance to Pettitt change point analysis. Trend analysis results pointed out that streamflow has a downward trend (Figure 3). The streamflow is expected to reach 1.93515 m<sup>3</sup> s<sup>-1</sup> in 2020 (Table 2).

Results of the non-parametric tests, Mann-Kendall test, change point and trend analysis, on the streamflow of Karamenderes river showed statistically insignificant (P>0.05) correlation between streamflow and climatic parameters.

Table 1. Results of Pettitt change-point analysis, Kendall's tau and Spearman's rho tests for climate parameters. <sup>a</sup>

Climatic Parameters	Pettitt Change Year	Mann-Kendall				Spearman			
		First Stage		Second Stage		First Stage		Second Stage	
		tau	p	tau	p	rho	p	rho	p
Karamenderes	1982	-0.189	0.243	-0.100	0.589	-0.308	0.186	-0.109	0.688
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

<sup>a</sup> First Stage is from 1962 to the change year and Second Stage is from the change year to 1997 for annual streamflow of Karamenderes River. 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. Forecasted values from trend analysis for annual streamflow of Karamenderes River and annual temperature, evaporation, precipitation.

Years	Karamenderes River ( $\text{m}^3 \text{s}^{-1}$ )	Temperature ( $^{\circ}\text{C}$ )	Evaporation (mm)	Precipitation (mm)
2016	2.86526	16.0341	205.128	48.3797
2017	2.63273	16.0629	206.572	48.2797
2018	2.40020	16.0916	208.016	48.1797
2019	2.16768	16.1204	209.461	48.0798
2020	1.93515	16.1491	210.905	47.9798

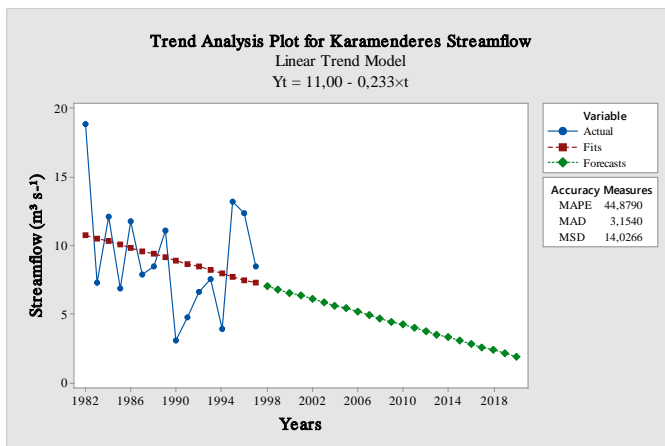


Figure 3. Trend analysis results for annual streamflow of Karamenderes River.

## Discussion

It is important to study the climate change impacts and to consider the outcomes of different climate change projects on the streamflow. Investigation of fluctuations in the streamflow is essential for management and planning of water resources. Durdu (2010) prevised that availability of the natural water resources will reduce in connection with the climate change and fluctuations in precipitation regimes in Turkey.

It is reported that the global warming might cause to increase in the temperature and evaporation by Chen and Xu (2005). Several authors documented decreasing trends in the river streamflow. Zhou et al. (2015) stated that there was a permanent reduce in Huangfuchuan river streamflow. Herawati et al. (2015) claimed that there was a decreasing trend in streamflow in the rivers of Indonesia. Pumo et al. (2016) pointed out that the streamflow and precipitation presented a significantly decrease in the rivers of Italy. Ozkul et al. (2008) and Ozkul (2009) found that there were downward trends in the streamflow of Büyük Menderes River and Gediz River. Türkeş and Acar Deniz (2011) reported that there was a decreasing trend in the streamflow of the rivers in the southern Marmara.

Many authors reported that climate change effects might lead to decreasing trends in the streamflow of rivers

(Bahadir, 2011; Durdu, 2010; Kahya and Kalaycı, 2004; Koçman and Sütgibi, 2012). It is expected that there were increase in the temperature and evaporation and decrease in precipitation and streamflow of Karamenderes River. The trends in the streamflow might not attributed to the precipitation variations at all times (Bates et al. (2008). Divergently, several authors pointed out that hydraulic structures (Ozkul et al., 2008), anthropogenic activities (Gao et al., 2011; Jackson et al., 2011; Salarijazi et al., 2012; Zhou et al., 2015) and agricultural activities (Durdu, 2010; Dügel and Kazanci, 2004; Kaçan et al., 2007; Yercan et al., 2004) could have effects on the streamflow of the river.

Alterations of hydro climatic environments and human activities would change the characteristics of the water resources of the Karamenderes River. Pınarbaşı dam and Bayramiç dam were constructed on the Karamenderes River in 1991 and 1996, respectively. Growth of population of the river basin is high. There have been agricultural and anthropological activities were realized to preservation or exploitation of water resources such as building dam and consuming water resources for irrigation or agricultural activities. The detected data presented that the temperature and evaporation have an increasing trend while precipitation and annual streamflow have a decreasing trend. Non-parametric methodologies based on ranks, for instance the change point analysis developed by Pettitt (1979), are advantageous in spotting changes in time series without parametric features. The incidents of change points and the trend pattern in streamflow and precipitation are relatively similar. Therefore, it can be concluded that the effects of hydro climatic circumstances are more important than the effects of anthropological activities such as dam building and actions for preservation or exploitation of water resources.

In conclusion, it is expected that there were increase in the temperature and evaporation and decrease in precipitation and streamflow of Karamenderes River. Climate change effects could have led to water stress or reduction of water resources. Therefore, management and planning of water resources should require to include in the scope the impacts of climate change and global warming. The present water management and planning policy should be reviewed and the most appropriate evaluation models should be implemented. It is suggested that dam building on the rivers might be beneficial to provide more water for irrigation or other purposes in sustainable way.

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