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Araştırma Makalesi/*Research Article*

Detecting Change-point in Seasonal Reference Evapotranspiration (ETo) datasets

Kadri YUREKLI[1]

[1]Department of Biosystem Engineering, Faculty of Agriculture, Gaziosmanpasa University, Tokat
(orcid.org/0000-0003-4938-663X)
*e-mail: kadriyurekli@yahoo.com

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Abstract: The aim of the current study in the Central Anatolia Region was on assessing the reference evapotranspiration (ETo) behavior as proxies in exposing the presence of climate variability. Historical climatic data spanning forty-three years (1970-2012) from the Turkish State Meteorological Service was used to calculate ETo data for five meteorological stations. The change–point in ETo dataset was revealed by the distribution-free CUSUM (Cumulative Sum) statistic technique. The two stations, named Ankara and Konya, had a statistically significant shift. None of the others showed significant variability in statistic sense.

Key Words: Central Anatolia Region, Reference Evapotranspiration, CUSUM approach.

Mevsimsel Referans Evapotranspırasyon Verisinde Değişim-Noktasının Tespiti

Öz: Orta Anadolu Bölgesindeki mevcut çalışmanın amacı, iklim değişkenliğinin varlığının belirlenmesinde belirleyici olarak Referans Evapotranspırasyon (ETo) davranışının değerlendirmesi üzerinedir. Meteoroloji Genel Müdürlüğünden alınan 43 yıllık (1970-2012) tarihsel iklim verisi beş meteoroloji istasyonu için ETo verisini hesaplamak amacıyla kullanıldı. ETo veri setindeki değişim noktası CUSUM istatistik tekniğiyle belirlendi. Ankara ve Konya isimli iki istasyonda istatistiki açıdan önemli değişim var. Diğerlerinin hiç biri istatistiki manada önemli bir değişkenlik göstermedi.

Anahtar Kelimeler: Orta Anadolu Bölgesi, Referans Evapotranspırasyon, CUSUM Yaklaşımı

1. Introduction

The increase in the greenhouse gases emitted to the atmosphere by human activities leads to changes in extreme weather events (Reason, 2007). Especially after the industrial revaluation, as well as the acceleration of population growth, deforestation and urbanization, too much consumption of fossil fuels has caused us to remain face to face with global climate change. Increasing greenhouse gases concentration in the atmosphere has destroyed the natural functioning of the hydrologic cycle. While air temperature rises up, on the other hand, this undesirable process has led to an increase in actual and potential evapotranspiration. Climate scientists have anticipated that climate change would affect our country in terms of drought. Of course, the impact of the expected this natural disaster will have on the agriculture sector, due to out limited available water resources and the use of 75% of the existing water in agriculture. Due to the seriousness of the problem, our citizen should be made aware on how important the optimal and uncontaminated use of water resources in our country is. To benefit from our available water resources effectively, the impact of the threat of global warming on our country should be done correctly analyze and, measures must be taken accordingly.

Mostly changes in rainfall and/or air temperature is considered by researchers when assessing the existence of climate change. However, the distribution of rainfall throughout the year shows significant differences in its amounts relative to the months when considering the Mediterranean basin rainfall pattern. In particular, because of an inherent drought in the months of July and August, heavy rainfalls occurring in some years disrupt the natural course of these months. This tricky situation leads to the

presence of an upward trend in these months. In this context, the use of reference evapotranspiration (ETo) data is reported to provide more accurate result in appraising the impact of global warming or other factors on climate elements (Ghafouri-Azar et al., 2018; Azizzadeh and Javan, 2015). Therefore, the change in climate elements will be reflected directly to the ETo, which is calculated by using its elements and represents the evaporation demand of the atmosphere in a special time of the year for a given region. There are many studies on ETo to evaluate the likely impact of climate change on ecosystems (Espadafor et al., 2011; Shirgholami et al., 2005; Dinpashoh et al., 2011; Tang et al., 2011; Yurekli et al., 2017;). The CUSUM (Cumulative Sum) procedure to detect change-point in the considered data was used by Palaniswami and Muthiah (2018) in rainfall and temperature, Karpouzos et al. (2010) and Muchuru et al. (2016) in rainfall, and Yazıcı et al (2012) in Turkish climate data.

The study is on assessing change-point of seasonal ETo dataset obtained from using climate data of five meteorology stations located in the Central Anatolia Region. The study was overcome with the CUSUM test.

2. Material and Method

The data sequences used as the material in the current study comprise climate components from five meteorological stations, named Ankara, Konya, Kayseri, Karaman and Afyon, in the Central Anatolia Region. The five stations are under the management of Turkish State Meteorological Service. The length of data belonging to the stations ranges from 1970 to 2012. Geographic coordinates of these stations are 39°58'21.7"N 32°51'49.3"E ,37°52'07.3"N 32°28'16.7"E,,38°41'13.2"N 35°30'00.0"E ,37°11'35.5"N 33°13'12.7"E ,38°44'16.8"N-30°33'37.4"E for Ankara, Konya, Kayseri, Karaman and Afyon, respectively. The components were considered to predict daily ETo datasets with the FAO56 Penman-Monteith approach for every meteorological station. The detailed description concerning with the approach is in the reference of Allen et al. (1998). The monthly Eto datasets were formed after concatenating daily Eto data. The datasets to be analyzed as seasonal were put together via summing monthly Eto data for the stations. The seasonal data sets for every station include four periods, called period one from January to March (S-I), period two from April to June (S-II), period three from July to September (S-III) and period four from October to December (S-IV), respectively.

Methodology to reveal change-point in Seasonal Eto

The presence of variability in hydro-meteorological time series is revealed by both parametric and non-parametric procedures (e.g., Huang et al., 2018; Mohammed et al., 2015; Tabari and Talae 2011; Espadafor et al. 2011; Abdul Aziz and Burn 2006; Hamed 2008; Liang et al. 2010). But some of these methods presuppose that the available data need to fit a certain probability distribution, especially parametric ones among them. Non-parametric approaches are usually better accepted in detecting variability in the variable related to climate. The non-parametric procedure, referred to in many studies, have been Mann-Kendal. The obligation to comply with any probability distribution of the data is not required when applying this procedure. The prerequisite for the Mann-Kendal is that there should not be serial dependence between the observations. Furthermore, there are also the methods, as graphical introduced by Sen (2012) and Holt, in which variability in the data is disregarded statistically. This study was conducted on ascertaining change-point in seasonal reference Eto datasets. The distribution-free CUSUM method was regarded as the aim mentioned above. The steps of the procedure are as follows;

The method is carried through on difference between successive observations and median concerning with the time series (Eto dataset) (Robson et al., 2000). It is a rank-based analysis procedure. Let "$X_1, X_2, X_3 \ldots X_n$" be a given time series, the test is formulated statistically as;

$$CS = \sum_{i=1}^{n} \mathrm{sgn}\left(x_i - x_{med}\right) \quad (1)$$

In Eq.(1), where n is the number of observations, X_i and X_{med} are the ith observation and the median of the Eto dataset, respectively. The sign function takes the following values depending on three conditions:

$$\mathrm{sgn}(x_i - x_{\mathrm{med}}) = \begin{cases} +1 & \text{if}(x_i - x_{\mathrm{med}}) > 0 \\ 0 & \text{if}(x_i - x_{\mathrm{med}}) = 0 \\ -1 & \text{if}(x_i - x_{\mathrm{med}}) < 0 \end{cases} \quad (2)$$

According to Eq.(1), a negative CS value evinces a higher mean than the earlier part of the data sequence. The statistic CS follows the Kolmogorov-Smirnov (KS). The test statistic value $\left(\max|CS|\right)$ calculated from the Eq.(1) is compared to the value of $KS_{1-\alpha}$ from Eq.(3) at the alpha significance level. The null hypothesis related to no change-point is rejected if the $\max|CS|$ test statistic is greater than the critical value at the significance level of α.

$$KS_{1-\alpha} = \begin{cases} \alpha = 0.01, & 1.63\sqrt{n} \\ \alpha = 0.05, & 1.36\sqrt{n} \\ \alpha = 0.10, & 1.22\sqrt{n} \end{cases} \quad (3)$$

1. Results

In the study, to reveal whether there is the existence of a significant change-point in Eto data in terms of statistic, the distribution-free CUSUM method were applied to four seasonal Eto data sequences obtained with the addition of monthly Eto dataset in succession for five meteorological stations. The detection method of change-point is an effective way to recognize the unsteady Climate in a given hydro-meteorological data. This detection is very crucial in the context of the natural functioning of the hydrological cycle. The results of the CUSUM test for the aforementioned stations are in Table 1 and Table 2. The null hypothesis based on the Kolmogorov-Smirnov (KS) in these Tables was formed on rejecting at the 5 % significance level.

Table 1. The CUSUM test results related to Ankara, Konya and Kayseri stations
Çizelge 1. *Ankara, Konya ve Kayseri İstasyonlarının CUSUM test sonuçları*

Season	Ankara station			Season	Konya station			Season	Kayseri station		
	|CS|	YC	*KS*		|CS|	YC	*KS*		|CS|	YC	*KS*
S-I	11	2000	8.9	S-I	12	1992	7.7	S-I	4	**	8.1
S-II	13	2000		S-II	12	1988		S-II	3	**	
S-III	8	1999		S-III	13	1987		S-III	3	**	
S-IV	8	1997		S-IV	12	1986		S-IV	8	1982	

Table 2. The CUSUM test results related to Karaman and Afyon stations
Çizelge 2. *Karaman ve Afyon İstasyonlarının CUSUM test sonuçları*

Season	Karaman station			Season	Afyon station		
	|CS|+	YC*	*KS*		|CS|	YC	*KS*
S-I	3	**	8.05	S-I	4	**	6.08
S-II	4	**		S-II	4	2000	
S-III	5	2003		S-III	5	**	
S-IV	3	2005		S-IV	3	1997	

+, the absolute value of the maximum CS
*, year of change
**, value attained in more years than one year

As can be seen from the Tables there are statistically significance change-point in the whole seasonal datasets of Konya station and in the seasons of the S-I and S-II for Ankara station while its remaining seasons have an insignificant change-point in terms of statistic. Furthermore, even in a 10% confidence level for Konya station, the null hypothesis was rejected. None of the seasonal data sequences for both Karaman and Afyon stations showed a significant shift. As well, there are change-point values attainedin more years than one year in some seasons of these

stations and Kayseri station. Yürekli et al. (2017) applied parametric unit root test to the same seasonal datasets in this study. The monotonic trend was detected in all the data of four seasons for Ankara and Karaman stations whereas there was a trend in the S-IV season of Konya and Afyon station. Ünlükara ve Yürekli (2014) used the Mann-Kendal test to analyze the presence of upward or downward trend for the Eto datasets in the current study. The increasing trend was determined for the data sequences of Ankara and Konya station. Kayseri and Karaman stations had a decreasing trend in the S-IV and S-III seasons, respectively, while there was an upward trend in the S-III season of Afyon station. So as to avoid an increase in the volume of the present study, the scatter graph of the absolute CS values with the 5 % significance level value of the KS was only indicated for the S-III season of Konya Station in Figure 1.

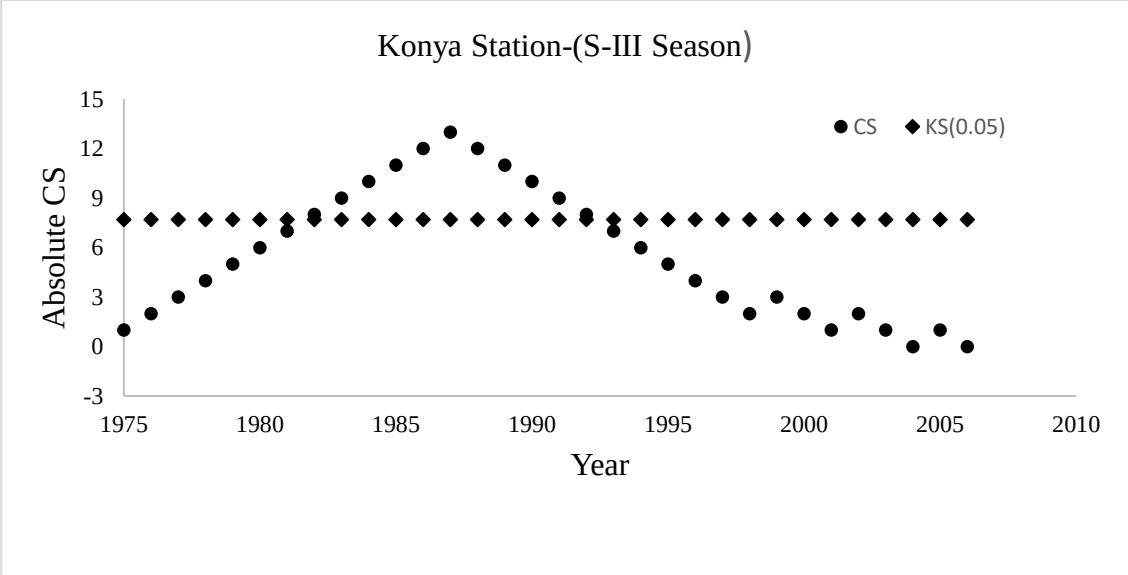

Figure1. The absolute CS values for the S-III season of Konya Station
Şekil 1. *Konya istasyonunun S-III periyodu için Mutlak CS değerleri*

3. Conclusion

The present study is related to change-point detection in the reference evapotranspiration (ETo) from five meteorological stations in the Central Anatolia Region. There were apparent significant shifts in the seasonal ETo data sequences in Ankara and Konya stations based on the CUSUM. The remaining stations have no statistically significant variability. The current position of the region should be monitored carefully and the necessary measures should be taken for the reliable development and operation of water resources, particularly in terms of both stations. Due to having a semiarid characteristic of the region, construction of the hydraulic structure (as dams or reservoirs) for irrigations and water supply and, reducing a minimum loss of water is vital in the area.

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