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Use of Different Statistic Approaches on Variability in Hydrologic Variables[#]

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ABSTRACT

The unnatural change in the globe under influence of devastating global warming has been quashing the overall functioning of ecosystem since industrial revolution. Thus, the human-induced disaster caused by proportional increase of greenhouse gases in the atmosphere has affected the normal functioning of hydrologic cycle. Under the undesirable condition, the amount of hydrologic variables began to diverge over time. Hydrologic variable should be homogeneous for the reliability of hydraulic structure while predicting necessary design criteria for its construction. Therefore, the test of whether this requirement is true should be performed in the context of any given hydrologic data's homogeneity before being passed to the implementation of statistical approaches to the data. The study carried out in Yesilirmak basin was realized on homogeneity of seasonal maximum streamflow data from eight gauging stations operated by The General Directorate of State Hydraulic Works (DSI). Yesilirmak River basin area is approximately 5% of surface area of Turkey. Yesilirmak River is one of the major rivers of Turkey and its long is 519 kilometers. There are three main tributaries of the Yesilirmak River, named as Kelkit, Cekerek and Tersakan. Its water is mostly used for purposes as irrigation, drinking, fisheries and wildlife. The parametric and non-parametric procedures, called as standard normal homogeneity, Pettitt, Buishand range and von Neuman ratio were used for this reason. Statistically significant inhomogeneity with respect to the all of the statistic tests taken into account in the study was detected in the considered streamflow data sequences presented.

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Hidrolojik Değişkenlerde Değişkenlik Üzerine Parametrik Olmayan Analizler

MAKALE BİLGİSİ

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Bushand sıra testi
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ÖZ

Yıkıcı küresel ısınmanın etkisi altındaki dünyada doğal olmayan değişim, sanayi devriminden bu yana ekosistemin genel işlevini bozmaktadır. Bu nedenle, atmosferdeki sera gazlarının orantılı şekilde artmasından kaynaklanan insan kaynaklı felaket hidrolojik döngünün normal çalışmasını etkilemektedir. İstenmeyen koşullar altında, hidrolojik değişkenlerin miktarında zamanla sapmalar meydana gelmektedir. Hidrolojik değişken, hidrolojik yapının yapımı için gerekli tasarım kriterlerini tahmin ederken hidrolojik yapının güvenilirliği için homojen olması gerekmektedir. Bu nedenle, bu gerekliliğin doğru olup olmadığının testi, verilere istatistiksel yaklaşımların uygulanmasına geçilmeden önce verilen hidrolojik verilerin homojenlik durumuna bakılmalıdır. Yeşilırmak havzasında yapılan bu çalışma, Devlet Su İşleri Genel Müdürlüğü (DSİ) tarafından işletilen sekiz ölçüm istasyonundan elde edilen mevsimsel maksimum akış verilerinin homojenliği üzerinde gerçekleştirilmiştir. Yeşilırmak Nehri havzası alanı, Türkiye yüzey alanının yaklaşık %5'idir.Yeşilırmak Nehri, Türkiye'nin en büyük nehirlerinden biri olup, uzunluğu 519 kilometredir. Yeşilırmak Nehri'nin Kelkit, Çekerek ve Tersakan olarak adlandırılan üç ana kolu vardır. Yeşilırmak suyu çoğunlukla sulama, içme, balıkçılık ve yaban hayatı gibi amaçlar için kullanılmaktadır. Bu sebeple standart normal homojenlik testi, pettit testi, buishand sıra testi ve von Neumann oranı olarak adlandırılan parametrik ve parametrik olmayan yöntemler kullanılmıştır. Çalışmada dikkate alınan tüm istatistiksel testlere göre verilen akış verilerinin istatistiksel olarak anlamlı homojen olmadığı sonucuna ulaşılmıştır.

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Introduction

Due to effect of global warming on hydrologic cycle, especially over last century, this human-induced disaster has begun to change the shape of frequency distribution dealing with hydro-meteorological variables. This has led to the deterioration of the desired homogeneity for hydrologic variables. Based on variation in temperature and precipitation patterns, its impact was quite self-evident by drought and floods events in many parts of the globe. Giorgi (2006) stated that Mediterranean region was enormously sensitive while being reported an increasing on heavy precipitation events in the last half of the 20th century in IPCC (2013). The assumption of stationarity in hydrologic variables is a need for construction of a reliable hydraulic structure. The predicted design value for the water-related structure is obtained based on statistical behavior of the hydrologic variable. The non-stationarity in the variables will influence planning, management and cost of the structure. In this sense, the data analysis should be fulfilled for solidity of hydraulic structure. Inhomogeneous data sequences should be homogenized to estimate design values with no doubt for any hydraulic structure.

Homogeneity analysis of hydro-climatic data can be performed by both parametric and non-parametric statistical methods. The most prominent feature of non-parametric methods according to that of parametric is that there is no pre assumption to comply with any probability distribution of data. Sen (2018) tested homogeneity of streamflow data sets predicted for rivers in Yesilirmak basin with Mann-Whitney U method. Yurekli (2015) applied the Mann-Whitney U test to judge on whether seasonal rainfall series from 19 rainfall stations over the upper Euphrates and Tigris rivers basin were homogeneous. Homogeneity condition was performed by using the double-mass curve technique for inhomogeneous data sets. Horwath et al. (2016) used standard normal homogeneity (SNHT), Pettitt(PT), Buishand range(BRT) and von Neuman ratio(VNRT) tests to detect change point in monthly, seasonal and annual discharge series. Kang and Yusof (2012) analyzed homogeneity of daily rainfall series by the same approaches considered in Horwath et al. (2016). Demircan (2018) carried out analysis on homogeneity concerning with streamflow series by Kruskal Wallis and Levene test. Yerdelen (2013) used run approach in testing whether mean annual discharge series came from the same distribution as well as applying PT and SNHT test to bring out change points in the data. The basic objective of the study is to apply the methods (SNHT, PT, BRT and VNRT) detecting change points in discharge data sequences from Yesilirmak basin.

Material and Methods

Yesilirmak River basin area which was selected as study region, is approximately 5% of surface area of Turkey. The river basin is situated between 39º 30' ve 41º 21' North latitude and 34º 40 've 39º 48' East longitude. Yesilirmak River is one of the major rivers of Turkey and its long is 519 kilometres. The river arises from Kosedag located in the northeast of Sivas province and, joins to Black Sea in district of Carsamba of Samsun province. There are three main tributaries of the Yesilirmak River, named as Kelkit, Cekerek and Tersakan. Its water is mostly used for purposes as irrigation, drinking, fisheries and wildlife. But, the river has been exposed to pollution due to population growth and rapid industrialization. In terms of land use, presence of forest, cultivated land and pasture land in the basin are about 39%, 39% and 19%, respectively. Due to irregular streamflow regime of Yesilirmak river, flooding in river basin occurs in various times, especially during the period in April, May and June months (Munsuz and Ünver 1983; Yürekli, 2017; Kurunç et al., 2005; Lekesiz et al., 2007).

In the study, data from eight streamflow gauging stations operated by The General Directorate of State Hydraulic Works (DSI) was used as a material. Some characteristics belonging to eight stations were given in Table 1. Its geographical locations is in Figure 1.

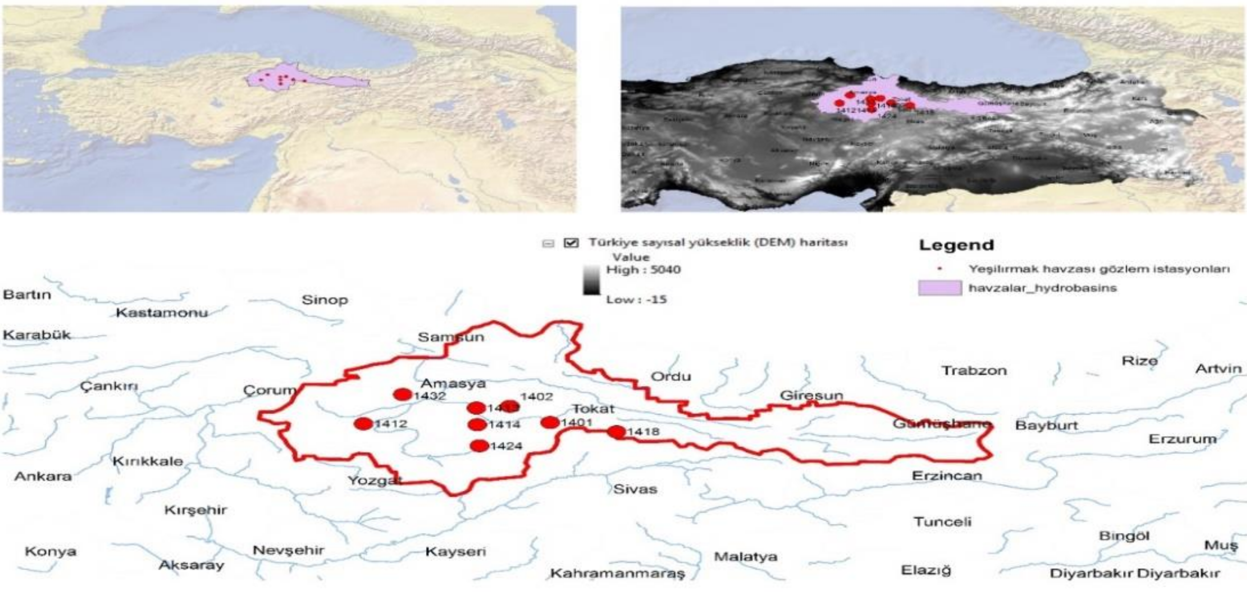

Figure 1 The Geographical Location and Stations of Yesilirmak Basin in Turkey

Table 1 The streamflow stations used in the study

Station Code	Streamflow (Location)	Longitude (East)	Latitude (North)	Record Length
1401	Kelkit Stream (Fatlı)	36°59'56"	40°28'42"	74
1402	Yesilirmak (Kale)	36°30'45"	40°46'18"	75
1412	Çorum Çat River (Seyhoglu Bridge)	35°25'03"	40°27'06"	60
1413	Yesilirmak (Durucasu)	36°06'43"	40°44'40"	58
1414	Yesilirmak (Sütlüce)	36°07'05"	40°26'03"	59
1418	Yesilirmak (Gömelönü)	37°07'43"	40°18'42"	51
1424	Çekerek Stream (Cırdak Bridge)	36°08'47"	40°0'29"	45
1432	Tersakan Stream (Ahmetsaray)	35°53'15"	40°59'13"	14

Table 2 Homogeneity test results of the station 1401

Season	PT		SNHT		BRT		VNRT	
	K	P	T_o	P	Q	P	N	P
S-I	1332	0.000	52.29	0.000	30.88	0.000	0.056	0.000
S-II	1332	0.000	58.81	0.000	31.05	0.000	0.009	0.000
S-III	1332	0.000	47.02	0.000	29.47	0.000	0.016	0.000
S-IV	1332	0.000	60.81	0.000	32.44	0.000	0.005	0.000

Table 3 Homogeneity test results of the station 1402

Season	PT		SNHT		BRT		VNRT	
	K	P	T_o	P	Q	P	N	P
S-I	1369	0.000	51.18	0.000	29.60	0.000	0.057	0.000
S-II	1369	0.000	44.21	0.000	27.48	0.000	0.019	0.000
S-III	1369	0.000	40.72	0.000	24.82	0.000	0.081	0.000
S-IV	1369	0.000	43.65	0.000	25.94	0.000	0.068	0.000

Table 4 Homogeneity test results of the station 1412

Season	PT		SNHT		BRT		VNRT	
	K	P	T_o	P	Q	P	N	P
S-I	870	0.000	47.44	0.000	12.32	0.000	0.301	0.000
S-II	870	0.000	33.51	0.000	19.94	0.000	0.212	0.000
S-III	870	0.000	42.89	0.000	23.11	0.000	0.012	0.000
S-IV	870	0.000	47.38	0.000	14.70	0.000	0.131	0.000

In the study, streamflows of the period in which there is the missing data were completed by using Grey System Theory (Wen, 2004). Monthly maximum streamflow value for each month of the relevant year was selected among the daily mean streamflows for the study. But, the study was conducted on the data sequences in four seasons, names of which were season-I (S-I), season-II (S-II), season-III (S-III) and season-IV (S-IV), respectively. The maximum data of each season was formed by selecting among monthly maximum streamflow values in October, November and December for S-I, January, February and March for S-II, April, May and June for S-III and, July, August and September for S-IV.

The homogeneity analysis of seasonal maximum data set from eight streamflow gauging stations was performed with the approaches, including Pettitt(PT), standard normal homogeneity (SNHT), Buishand range(BRT) and von Neuman ratio(VNRT) tests. A detailed description of these methods was not intended for the purposes of reducing volume in the article. These approaches are disclosed in the literature in detail (Amjadi, 2015).

Results and discussions

The four homogeneity tests abbreviated as PT, SNHT, BRT and VNRT by considering 5% significance level was applied to the seasonal maximum steramflow series from Yesilirmak River and its tributaries. The null hypothesis (H_o) of these homogeneity tests deems that the data sets are homogeneous while alternative hypothesis (H_1) assumes that there is a change in the data. The null hypothesis (H_o) is rejected when the calculated P-value belonging to any homogeneity approach is lower than the critical value (5%), then the alternative hypothesis (H_1) is accepted. The results of these four tests are presented in the following tables. The test statistic measures (K, T_o, Q and N) for every homogeneity procedure and their corresponding probability values (P) are given in the tables (Table 2, 3, 4, 5, 6, 7, 8, 9). As can be seen in all tables, the aforementioned homogeneity tests detected inhomogeneity or the existence of a change in streamflow data sets of four seasons for each station considered in the study.

According to categorization in Schonviese and Rapp (1997) whose classification related to precipitation is doubtful, suspect and useful if the rejection of the null hypothesis is realized in the two, three or four and one or none of the homogeneity procedures given in the study, respectively. The results of the study imply that all data sequences are suspect with respect to the above classification. But, these four tests in some researches presented the inconsistent results (Feng et al., 2004; Sahin and Cigizoglu, 2010; Omar et al., 2017). In this context, Omar et al. (2017) and Talaee et al. (2014) drawn attention the relationship between data homogeneity and reliably detecting trend.

Table 5 Homogeneity test results of the station 1413

Season	PT		SNHT		BRT		VNRT	
	K	P	T_o	P	Q	P	N	P
S-I	812	0.000	37.88	0.000	18.31	0.000	0.114	0.000
S-II	812	0.000	37.37	0.000	23.01	0.000	0.065	0.000
S-III	812	0.000	37.88	0.000	22.32	0.000	0.044	0.000
S-IV	812	0.000	45.30	0.000	14.43	0.000	0.562	0.000

Table 6 Homogeneity test results of the station 1414

Season	PT		SNHT		BRT		VNRT	
	K	P	T_o	P	Q	P	N	P
S-I	841	0.000	43.48	0.000	24.64	0.000	0.011	0.000
S-II	841	0.000	38.57	0.000	23.60	0.000	0.026	0.000
S-III	841	0.000	38.94	0.000	23.78	0.000	0.014	0.000
S-IV	841	0.000	33.95	0.000	21.12	0.000	0.080	0.000

Table 7 Homogeneity test results of the station 1418

Season	PT		SNHT		BRT		VNRT	
	K	P	T_o	P	Q	P	N	P
S-I	625	0.000	38.18	0.000	17.82	0.000	0.042	0.000
S-II	625	0.000	25.25	0.000	17.24	0.000	0.224	0.000
S-III	624	0.000	35.12	0.000	21.03	0.000	0.012	0.000
S-IV	625	0.000	36.37	0.000	16.76	0.000	0.047	0.000

Table 8 Homogeneity test results of the station 1424

Season	PT		SNHT		BRT		VNRT	
	K	P	T_o	P	Q	P	N	P
S-I	484	0.000	42.02	0.000	7.47	0.000	0.832	0.000
S-II	484	0.000	30.28	0.000	18.29	0.000	0.026	0.000
S-III	484	0.000	28.25	0.000	17.37	0.000	0.061	0.000
S-IV	484	0.000	34.91	0.000	15.98	0.000	0.035	0.000

Table 9 Homogeneity test results of the station 1432

Season	PT		SNHT		BRT		VNRT	
	K	P	T_o	P	Q	P	N	P
S-I	42	0.000	10.30	0.000	5.51	0.000	0.138	0.000
S-II	42	0.000	8.67	0.001	5.37	0.001	0.177	0.000
S-III	42	0.000	11.03	0.001	5.75	0.001	0.156	0.000
S-IV	42	0.000	11.24	0.004	4.55	0.000	0.324	0.000

Conclusion

The study was conducted to check whether the seasonal data sequences from streamflow gauging stations on Yesilirmak river and its tributaries were homogeneous or not. In this sense, the four homogeneity procedures, named Pettitt(PT), standard normal homogeneity (SNHT), Buishand range(BRT) and von Neuman ratio(VNRT) were used for the mentioned goal. All of the data sets showed an inhomogeneous character. This implies a threat of a setback in accomplishing the expected benefit from any water-related structure. Reliably predicting design value required for the construction of any hydraulic structure is very important for building safety. This can only be achieve with reliable data. A homogeneous hydrologic data is crucial to reach to the reliable design value.

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